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ABSTRACT

This book is part of a series of case studies that demonstrate better ways to educate Ohio's students. The case study is part of the Transforming Learning Communities (TLC) Project, designed to support significant school-reform efforts among Ohio's elementary, middle, and high schools. This report describes the implementation of an innovative program at an elementary school in northern Ohio. The text focuses on the school's efforts in mathematics-instruction reform. It examines the research that structured the reform and its impact on school change. The reform efforts are further elaborated through a series of five vignettes that portray the changes occurring in mathematics instruction. The report then provides background information about the two principals who played significant parts in reform efforts and the dialectical relationship between tensions and reform that developed. It looks at the emergence of a critical mass of reform-minded teachers and the effort required to change the structure of leadership, instruction, and assessment. The last chapter describes the complexities of change, the alterations to epistemology, the presence of chaos, and the need for teachers and principals to believe in the reculturing of the school. Two appendices provide the study methodology and samples of performance tasks. (Contains 52 references.) (RJM)

OHIO

TRANSFORMING LEARNING COMMUNITIES

A Paradoxical Path To Reform

The Case Study of Lomond Elementary School

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TRANSFORMING LEARNING COMMUNITIES

A PARADOXICAL PATH TO REFORM:

THE CASE STUDY OF LOMOND ELEMENTARY SCHOOL

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"... megachange in education may only occur through a grassroots approach, the emergence of *little schools* ..." (Papert, 1993)

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Ohio Department of Education

Columbus, Ohio

1999

Dear Readers:

The 12 Transforming Learning Communities case studies enlighten readers about the search for better ways to educate Ohio's young people. The stories, told by educators themselves, paint a realistic picture of schools in Ohio.

The unique and inspirational perspectives of the school people highlight the triumphs of team spirit, the drive to turn obstacles into opportunities, and the effort to consider complex questions and find answers that lead to higher student achievement. These researchers tell stories of success and frustration in the endeavor to make life better for future generations.

At the core of educational change is a long-term commitment to teaching and learning that has the potential for creating positive change throughout society. The case studies emphasize intense, high-quality professional development; increased service to others; a holistic approach to education; the promotion of a sense of community; and a deepened understanding of the daily work in the classrooms, corridors, and boardrooms of public schools.

The educators at the heart of change encourage us to examine and refresh our views about schools. Sincere thanks is extended to the local educators, university researchers, and concerned citizens for their willingness to examine the lessons from the past, the realities of the present, and the likely consequences of change.

Sincerely,

Linda C. Nusbaum

Linda C. Nusbaum
Research Project Manager

Transforming Learning Communities Project

INTRODUCTION

The Transforming Learning Communities (TLC) Project was an initiative funded by the Ohio Department of Education (ODE) to support significant school reform efforts among Ohio's elementary, middle, and high schools. Education researchers associated with the International Centre for Educational Change at the Ontario Institute for Studies in Education of the University of Toronto were contracted to undertake in-depth case studies of school improvement in a select number of schools supported by Ohio's Venture Capital grants. The aim was to understand the school improvement efforts in these schools, and to engage other Ohio educators in the lessons learned from these schools' experiences.

The project title communicates the orientation to the study. "Learning communities" is a metaphor for schools as learning places for everyone (especially students and teachers) who has a stake in the success of schools as educational environments. "Transforming" signifies that the schools are in a process of change, and that the changes they are striving to achieve involve fundamental reforms in teaching and learning, assessment, organization, professional development, and/or governance. Transforming also captures the intent of the project to support — not just to document — the process of change in participating schools.

The TLC Project began in the Spring of 1997. A three-stage process was used to identify and select schools that had demonstrated notable progress in their efforts to implement significant change over the preceding three to five years: (1) solicitation of nominations from ODE staff familiar with the Venture Capital schools, corroborating opinions from independent sources (e.g., Regional Professional Development Center staff), and statistical profiles for nominated schools (e.g., performance and demographic data); (2) telephone interviews with the principal of each nominated school; and (3) ranking of schools according to relevant sampling criteria. Twelve schools were chosen for variation in type (elementary, middle, secondary); location (rural, urban, and suburban from various regions in Ohio); focus for change (e.g., teaching and learning, professional growth, school-community partnerships); school improvement model; and evidence of progress.

The individual case studies were carried out during the 1997/98 school year by teams consisting of at least two members of the school staff and researchers from four Ohio universities that partnered with the schools. Each team designed and implemented a multi-method study of school improvement activities and outcomes in their school learning community. These included interviews, observations, surveys, and documents. While each case study reflected the unique character of school change at each school, the studies employed a common conceptual framework to guide their exploration and analysis of change in these school learning communities. The TLC framework oriented the case study teams to investigate change and change processes in multiple contexts — the classroom, the corridors, and the community — and in relation to three key processes of learning in organizations: collaboration, inquiry, and integration.

The major products of the Transforming Learning Communities Project include 12 individual case study monographs, a cross-case study and handbook, and a companion video at www.ode.ohio.gov.

TABLE OF CONTENTS

PROLOGUE

HIRING INTELLECTS, INDEPENDENT THINKERS, AND MOTORCYCLE MECHANICS

"I don't recommend that you hire him. He could be a project for you to refine. He isn't the typical Shaker teacher." (comment to the Lomond Elementary School principal, circa 1990)

"I'm sending you someone who probably will fit in your building. They march to a different drummer." (comment to the Lomond principal, circa 1994)

Glaring sunlight streamed through tall windows, exposing a need for cleaning. The principal's office, although decorated in cool, grass-green tones, was uncomfortably hot. A young woman sat rigidly on the edge of chair, trying to cloak her nervousness with feigned attentiveness. She was not happy with the current situation. The interview was not what she anticipated. She was angry that she appeared unprepared. Her responses, she felt, lacked focus and depth, and she worried that her superficial comments were evident to both the principal and the assistant principal.

Friends, already employed in the school district, had warned her about interviewing here. "It won't be the standard, scripted interview questions. They will discuss theory and philosophical stuff. They're big on learning — children's learning, math learning, and your learning. Don't bother bringing your portfolio; you won't need it." Her friends were right: the questions were unrelated to teaching. They were more about learning. The principals seemed more interested in what she thought than in what she could do. She remembered the portfolio she brought to the interview. She had given it to the assistant principal; it rested now, unopened, on the floor next to the assistant principal's chair.

"Have you ever read *Pirsig's Zen and the Art of Motorcycle Maintenance* [1974]" asked Larry, the Lomond principal.

Lynn, the assistant principal, prepared herself for an extended interview: Larry's question had telegraphed an interest in the applicant. The question targeted the woman's intellectual habits. Larry, a former English teacher, was always interested in what teachers read. He was most happy when someone had read one of his favorite books. Lynn smiled. He was also happy if the applicant had a Jesuit education, like he had. Larry often reminded Lynn:, "One thing about those Jesuits, no one graduates without taking philosophy — the intellectual stuff. If it wasn't for those Jesuits, the decisions I make would have no philosophical or theoretical foundations. A lot of managers make decisions with no philosophical base. That's a problem."

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Teachers made fun of what Larry read. Books on Kant, Sartre, and Dewey — along with books by Tom Peters, Robert Frost, and Ilya Prigogine — littered his desk and office. Lynn looked over at Larry's desk; he had ignored his secretary's plea to "tidy up and make a good impression." She wanted to laugh. Larry wasn't interested in making good impressions; he was interested in *doing things differently.*

Lynn now redirected her attention to the interview. Something had triggered Larry's sudden interest in this applicant. Thus far, the woman's responses had been superficial. Perhaps, Lynn thought, the woman had a different academic background. Larry believed that degrees in other disciplines were instrumental for school change. "How can you make a difference in learning without teachers schooled in other disciplines? Elementary education needs to be energized — there's too much 'sameness.' It leads to narrow and parochial thinking. That's not what we need to improve learning. We need to find different kinds of people."

They had been successful in finding *different* educators. Several of the "teacher-leaders," including themselves, held degrees in economics, social work, English, graphic design, history, political science, sociology, and psychology. They had also been successful at developing a strong university and secondary education partnership. University professors and secondary mathematics educators taught in classrooms and worked with teachers to design mathematics instruction. This partnership improved mathematics instruction and influenced the direction of the reform.

Lynn remembered that Larry was influenced by Tom Peters (1984) on organizational change. Larry especially liked Peters's "the crazies down the hall" strategy for making major change. He often reminded Lynn about the importance of hiring risk-takers and independent thinkers. Larry wanted teachers "cast in a different mold. That's what we need. Tom Peters believes change only happens when you go with the 'crazies down the hall.' Well, I am trying to go with some 'crazies,' and this looks strange to some people."

The woman being interviewed didn't appear to fit the crazy category. Lynn quickly scanned the woman's resume — degrees in economics and mathematics, and successful experiences with adults and children. Her credentials looked good. Lynn reminded herself to pay attention to the interview. Soon it would be her turn to ask some questions. Usually, Larry left the instructional questions for her. "You zero in on the heart of the matter — what teachers do with kids in classrooms." So she waited for her cue.

Learning mathematics was at the heart of their mathematics reform. It was essential that new teachers be able to implement the Standards of the National Council of Teachers of Mathematics and understand how young children learn mathematics. The mathematics reform they championed hinged on teachers' abilities to take risks, expand their mathematical knowledge, and create learning situations for young children. This, Lynn recollected, was not easy for teachers to do. She remembered one teacher's concern: "You expect me to teach probability and model my thinking for students? My last math class was in high school. I don't know probability." Reform efforts required teachers to do things differently, to become learners, to build and to understand that knowledge wasn't dispensed to students. Rarely did most applicants understand the theories and complexities of learning. Instead, they had a strong sense of curriculum and methods but were weak on learning and assessment. Like Larry, Lynn believed that the school needed people who "marched to a different drummer."

Over the last eight years, Lynn had watched as Larry grew more frustrated with applicants who came marching to a predictable, unimaginative educational beat. New teachers continued to have more technical than intellectual training. They needed individuals who could fit the role of intellectual, as well as reformer.

There were other barriers to change. Traditional organizational structure stymied re-culturing efforts. The traditional culture did not encourage teachers to change the nature of their work. Nor did it actively support teacher as *instructional designer, decision maker,* or *instructional leader*.

Time was also an enemy — never enough time for learning. Lynn thought about how Larry hated the idea of long vacations. "How do you expect children to learn when schools close for 14 weeks a year? Just run a factory like that and see how long you stay in business. You want to improve achievement in mathematics? Make kids come to school most the year." His remarks were not always popular. Lately, though, Lynn noticed that there were some people starting to agree with Larry: that improved achievement may need an expanded school year. Larry was always happy to have someone agree with him. He felt that his role was sometimes to "plant seeds that might grow later," even though he knew that he might not live long enough for these seeds to germinate.

The Ohio Fourth Grade Proficiency Test was now another major frustration. The teachers were surprised that, despite much research suggesting schools were not improved by multiple-choice, high-stakes testing, most governmental leaders and the general public still believed that state testing programs would improve schools. It frustrated some Lomond educators that the proficiency test was the sole indicator of student achievement and their school's effectiveness. Larry would often remind them that, "until we have something else in place — a more authentic way to assess student growth — standardized testing will reign." The teachers were trying to design something more authentic that would capture student growth in mathematics. But it wasn't easy. And they needed more time.

The interview was in full swing now. Larry was interested enough to ask the applicant her views on learning.

"What do you think of Piaget's learning theory? How do these theories apply to practice?"

"In my opinion," she responded, "I think Piaget is too narrowly interpreted by early childhood specialists. They seem to stencil their interpretation onto developing children, and often this limits the kinds of experiences the children have." She shifted slightly in the chair. "I've had more than one argument about what is and is not 'developmentally appropriate practice' with some of my friends. What they seem to miss is that Piaget's theory is stage theory of development. To think that children all learn in a 'lock-step' fashion is unrealistic. I believe children are individuals. *They* tell *me* what they can appropriately experience. Some theorists now believe that young children are quite curious about abstract ideas. I think that little kids can deal with both abstract ideas and concrete models."

Lynn looked across the room at the woman. In some ways she felt guilty. There should be some way to explain to the applicant the impact of the reform and how hard she would have to work. The reform was humbling and scary for some teachers. Lynn remembered the reaction of a teacher who transferred to Lomond to join the reform. "You didn't tell me it would be this hard. I've taught for 10 years already. Here, I feel as if I'm a new teacher."

Lynn heard her cue. Larry was finished with his part. The applicant looked relieved to change interviewers. Lynn turned and leaned toward the woman.

"Suppose a first grader says to you, 'There are 24 hours in a day, but I'm not sure how many hours in a night. I think it has less hours because night goes faster.' How would you respond to the child's comments?"

Chapter One

Diverse Landscapes

In this chapter, several landscapes are introduced. To understand how a mathematics instructional reform and an epistemological shift ignited major school change, it is important first to paint a clear description of the physical setting (local landscape) that surrounds and nurtures evolving changes within Lomond Elementary School. Within the local landscape reside two other landscapes that are part of Lomond's contribution to the educational community. The historical landscape focuses on pivotal events and activities that have molded and been created within the reform process since 1989. The research landscape provides a glimpse of what research undergirded the reform and its impact on school change at Lomond. Also discussed in the research landscape are the importance of understanding the nature of instructional change in schools and the challenges that instructional changes pose for school leaders.

Local Landscape

Nestled alongside the boundary of the city of Cleveland is the city of Shaker Heights, Ohio. The city, along with other inner-ring suburbs and parklands, form a necklace of prime residential communities that completely embrace Cleveland and Lake Erie.

The city of Shaker Heights, a "Historic Landmark" district, is known for the architectural beauty of its homes, its expansive parks, its city services, and its excellent public school system, the Shaker Heights City School District. Citizens take pride in the national reputation of the Shaker Heights schools: a reputation for quality instruction and a senior high school that is one of the top-rated senior high schools in the country. The school system enjoys strong community support. Residents pay the highest voluntary school taxes in Ohio. The Shaker Heights schools also benefit from active parent involvement, with "armies" of volunteers who work with children and help raise additional funds to supplement the instructional program.

Since the 1960s, Shaker Heights, originally a "planned community" for wealthy industrialists, has been home to 32,000 residents of diverse cultural, racial, and socioeconomic backgrounds. The city, along with a handful of other communities in the nation, is also known for its long-standing commitment to integration. Thirty-five percent of the city's population is African-American, whereas the population of the school district, which encompasses the city of Shaker Heights and a small portion of the city of Cleveland, hovers between 48 and 53 percent African-American. Strong commitments to integrated neighborhoods and public schools are dominant characteristics of, what has been called by some, a social experiment. A multicultural community, fine housing, proximity to Cleveland, and a fine, integrated public school system attracts families from all over the United States.

The commitment to integrated schooling, coupled with a declining school population, led to the reorganization of the district's elementary schools. This proposed plan to close four neighborhood elementary schools, redraw school boundaries, create five kindergarten-through-fourth-grade schools, and one fifth-through-sixth-grade school, and reassign all elementary staff was hotly contested for two years. The closing of four of the city's nine elementary schools was a marked departure from the Shaker's tradition of neighborhood schools, where students often walked home for lunch and where the local elementary school defined the local community, as well as real estate prices.

In 1986, Lomond Elementary School opened with a new teaching staff that lacked (according to local folklore) any "superstar" teachers and a student population of 495 students, of which over half were attending Lomond for the first time. The "new" Lomond community consisted of parts of three different school neighborhoods, which contributed to a racially balanced school.

Since 1990, Lomond has been the largest kindergarten-through-fourth-grade school in Shaker Heights. Its student population is 565 (54% African American, 42% white, 6% other racial or multiracial groups). About half the students walk to school, while the other half either ride buses or come in cars. One hundred students participate in a Before/After Care program housed at Lomond, which is managed and operated by the city's recreation department. The school has 25 classroom teachers, five special-area teachers (art, music, physical education, library), two Learning Disability teachers, approximately 20 full and part-time support staff (tutors, Reading Recovery teacher, district specialists, school psychologist, occupational/speech therapy, nurse), one principal, one assistant principal, one administrative secretary, and one office clerical aide. The average class size is approximately 22 students.

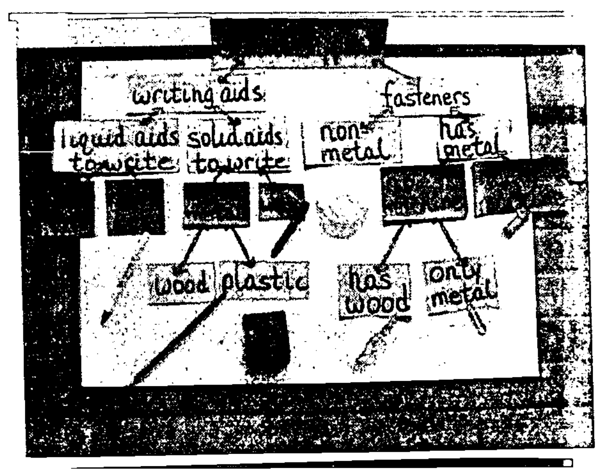
Geographically, the Lomond community is at the southern edge of Shaker Heights and borders the predominantly African-American community of Warrensville Heights. Lomond is a middle-class neighborhood that is well integrated and in which there is less socioeconomic diversity than in other neighborhoods in Shaker Heights. The neighborhood housing consists of single- and multiple-family units. The variety and the cost of housing attract young families, professionals, and individuals who want to move from urban settings.

Lomond School sits atop a large, sprawling campus that holds two baseball diamonds, a soccer field, and an ultra-modern playground that is good for climbing and that is artistically landscaped to blend into its surroundings. The campus is the center of neighborhood gatherings and sporting events. The campus is outlined by rows of 200-year-old oaks. Tree-lined streets and sturdy brick and wood-frame houses reflecting various architectural styles encircle the campus. The large 70-year-old red brick and slate-roofed Georgian building resembles most Shaker Heights schools. The architecture and its landscape are reminiscent of a private — not public — school setting.

The overall architectural details of the school seem to reflect the community's pride in schools. The dignity of the architecture manifests itself in bay windows, crown molding, solid oak doors, brass doorknobs and railings, marble window sills, wide ceramic-tiled, hallways, 12-foot oak windows, 15-foot ceilings, a double gymnasium, and an auditorium with a stage, balcony, and projection room. The peaked attic and the catacombs in the basement provide storage. Basement tunnels leading to the old coal bin under the playground are now used by fourth-grade students during tornado drills. Generally, the U-shaped floor plan is predictable. Classrooms, like the trees, outline the perimeter of wide hallways. The classrooms are undifferentiated, over-stuffed, evenly spaced cubicles gated by oak doors. No classroom is "across the hall" from another. The placement of the rooms, rather, seems to intentionally isolate students and teachers from others in the school.

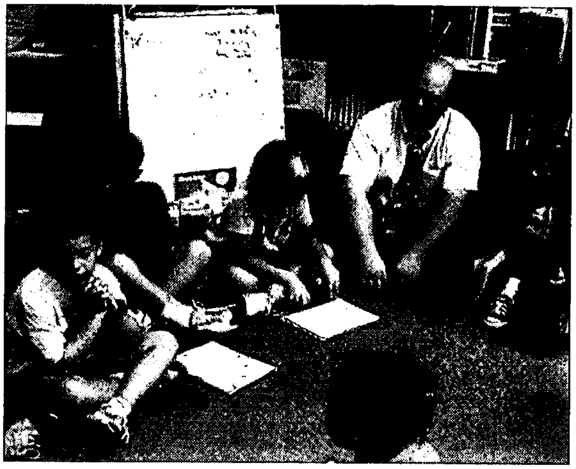
Student work — primarily in mathematics, science, and writing — litters the brick walls. Student papers, devoid of teacher comment or grade, are mostly teacher-designed. Mathematics solutions are shown through words, illustrations, and calculations.

FOURTH GRADERS GRAPH DAILY LENGTH OF PENCILS TO SHOW AMOUNT OF SHARPENING



CLASSIFYING SCHOOL SUPPLIES

Classroom settings are also teacher-designed. Many classrooms have similar characteristics, such as (1) classroom libraries, (2) large, carpeted areas on which students and teacher can congregate away from desks and tables, (3) computer centers, (4) bookcases full of literature books and mathematics materials, and (4) such home furnishings as rocking chairs, sofas, throw pillows, and stuffed animals.



SECOND GRADE MATHEMATICS
PROBLEM SOLVING

KINDERGARTEN STUDENTS
COMPARE NUMBERS

Historical Landscape

In 1989, two major publications addressed the issue of reforming mathematics education in America. These reports proposed wide-ranging, radical changes in mathematics learning and teaching. In *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (1989), the National Research Council (NRC) concluded that ineffective mathematics education posed a potential threat to America's economic security in a technological world. In *Curriculum and Evaluation Standards for School Mathematics* (1989),The National Council of Teachers of Mathematics (NCTM) echoed similar views and drafted recommendations intended (1) to expand school mathematics beyond "shopkeepers' arithmetic," (2) to include mathematical meaning congruent with the needs of the twenty-first century, and (3) to establish instructional beliefs and practices based on the epistemological foundations of constructivism. The following describes pivotal events impacting Lomond school reform since 1989.

Spring 1989 — *Curriculum and Evaluation Standards and Everybody Counts* (National Council of Teachers of Mathematics) (National Research Council) published. Documents call for major reform in mathematics instruction at the kindergarten through fourth-grade level, where the sole reliance on "shopkeepers' arithmetic skills" did not develop mathematical literacy. Recommendations call for expanded mathematical content, expanding elementary teachers' content knowledge, and a change in mathematics instruction.

Winter 1990	Public-private match grant written requesting funds to align mathematics to the NCTM recommendations. Intent of grant is to develop hands-on lessons in all the strands of mathematics — probability, estimation, patterns, functions, geometry, number sense, and data collection. Grant monies purchase new concrete materials in mathematics. Private partners are Key Bank and Tremco, Inc. Amount of grant: $50,000.
Spring 1990	Grant awarded by the Ohio Department of Education.
Summer 1990	Kindergarten-through-fourth-grade teachers and the assistant principal, in consultation with a university mathematics educator (Cleveland State University), write mathematics lessons (*Umbrellas*, Cowen et al.). Lessons incorporate the use of concrete materials in all the strands of mathematics and attempt to integrate mathematics into other areas of the curriculum, such as social studies, science, and language arts.
1990-1995	Five Effective Schools grants awarded by the Ohio Department of Education. Grants used to finance mathematics and science instructional reform. Amount of grants: $20,000.
Fall 1990–Summer 1991	*Umbrellas* implemented at Lomond. University mathematics educator conducts staff workshops throughout the year to demonstrate use of mathematics manipula tives in mathematics lessons.
Summer 1991	*Umbrellas* revised. District teachers work with Lomond teachers to write mathematics problem solving for kindergarten-through-fourth-grade instruction (*Investigations*, Lucci et al.).
Fall 1991	*Umbrellas* and *Investigations* disseminated to district kindergarten-through-sixth teachers.
Fall 1993	Ohio Department of Education initiates Venture Capital grants for school improvement. Grants are to "spark systemic change at the school level and to encourage risk-takers who want to create a more effective educational system."
Winter 1994	Venture Capital Grant awarded to Lomond Elementary School. Grant aligns mathematics and science instruction with national research recommendations, focusing curriculum on key concepts, developing relevant lessons based on students' prior experience, and applying constructivism to mathematics instruction. Total amount: $125,000 over five years ($25,000 per year).
Summer 1994	Principals-led team of kindergarten-through-fourth Lomond educators (included two secondary mathematics educators, one secondary science educator, one uni-

versity mathematics educator) wrote mathematics lessons that focused on students' experience, integrated mathematics into science, and applied constructivist practice to mathematics. (*Perspectives*, Cowen et al.).

Fall 1994	*Perspectives* implemented in some Lomond classrooms. Lessons fail to develop constructivist model of instruction. Too much reliance on calculation. *Perspectives* is shelved; decision is questioned by some members of the writing team.
Fall 1994	Language in Venture Capital grant proposal (which all Lomond teachers signed) provokes union leaders. A section in the proposal, entitled *Hindrances and Alterations*, states, ". . . In our opinion these present educational policies and practices hinder reform efforts. . . . 8) Administrative and union practices which do not genuinely support or encourage innovation and, therefore, equalize performances at a mediocre level need to be redesigned so that educational leaders encourage and support innovation and allow risk-taking behaviors outside the 'bounds' of normal rules and regulations."
Fall 1994	Decision to have university mathematics educator model constructivist practice for teachers. Lomond project used in research study.
Late Fall 1994	Classroom mathematics dialogues between university professor and fourth-grade students reveal that what is taught is often not what is learned. Focus of project focuses on how students think and what they understand.
Late Fall 1994	First Shaker Heights school levy fails. District sustains a $6 million loss. Anti-tax group exposes underachievement issues, specifically among African-American students. Anti-tax group pressures school board, suggesting that achievement will improve through direct-instruction and "drilling" the basics. Group begins using local newspaper to regularly criticize school district.
Fall 1994	Principal forms evening parent mathematics group to communicate instructional reform to public.
Winter 1995	Dissertation, *The impact of the NCTM Standards (1989) on the professional lives of elementary educators: A portrait of radical change* (Cowen, 1995), written about Lomond reform efforts. The dissertation links constructivism to major reform agendas, viewing a change in existing educational epistemology as "radical" and a "paradigmatic shift" for educators.
Spring 1995	Key mathematics concepts and processes identified by elementary, secondary, and university educators. Mathematics instruction focuses on the ideas of unit, change, chance, unitized systems, dimensionality, location in space, and zero to infinity (number) and the processes of combining, comparing, and partitioning.

Summer 1995	Disagreement with university consultant on decision-making role forces principals to limit consultant's role. Secondary mathematics/science educators assume consultant's role. They develop workshops and regularly observe/teach in kindergarten-through-fourth-grade classrooms.
Summer 1995	"Families Talking Math" group meets with principal to develop a parent support group for reforming mathematics education. Group develops ways for parents and children could do mathematics together at home.
Fall 1995-Spring 1996	Families Talking Math begins writing mathematics problems for kindergarten-through-fourth-grade students to take home and do with parents.
Fall 1995-Spring 1996	Kindergarten-through-fourth team works with university professor to design a framework of lessons that target key concepts in mathematics. University professor recommends that principals not participate in staff-development meetings and force change on teachers. Staff development targets key mathematical ideas of probability, length, area, volume, time, and money.
Fall 1995	Teachers asked to submit action-research proposals. Eighteen teachers volunteered to conduct action research that targets constructivist teaching-learning-assessment practices. Individual proposals are aligned with national reform efforts in mathematics. Proposals are funded to buy materials, equipment, and release time. Art specialist designs authentic assessment portfolios for students; student artwork would be collected for five years.
Fall 1995	Parent-Teacher-Student conferencing — "triangular conferencing" — begins in some Lomond classrooms.
Spring 1996	Ohio Fourth Grade Proficiency Testing begins.
Spring 1996	The Kumon Mathematics Program, an Asian mathematics program based on quick performance of computational skills, is piloted at Lomond to help underachieving Lomond students pass the Ohio Mathematics Proficiency Test.
Summer 1996	Kindergarten-through-fourth teachers, secondary mathematics educators, and principals design a performance task assessment system (*Snapshots;* Cowen et al.). Students solve problems using models, illustrations, words, and computations. Performance tasks are given two to three times a year to capture student's cognitive growth in mathematics. (See Appendix B for examples of performance tasks.)
Summer 1996	Team of kindergarten-through-fourth teachers works with assistant principal and secondary science educator to identify the key concepts in science. Concepts are change, force, living, non-living, and chance. Initial framework of science lessons are designed using these concepts.

Summer 1996	University mathematics professor resigns from project.
Fall 1996	*Snapshots* is implemented. Participation in reform becomes mandatory. All classroom teachers and tutors are placed on one of four kindergarten-through-fourth Instructional Design Teams (IDTs) led by two teacher-leaders. Tensions emerge over the selection of teacher-leaders, specifically the appointment of non-tenured and less senior teachers as leaders, and the fact that the reform is no longer voluntary. Tensions also emerge over instructional changes. A few teachers label the instructional reform "developmentally inappropriate."
Fall 1996	IDTs meet six hours each month to build a framework of lessons that target performance tasks. Permanent substitutes are hired and trained to cover classes one day a week to facilitate staff development.
Fall 1996	Some teacher-leaders conduct weekend and evening conferences. Some teacher-leaders petition the union leadership to negotiate for additional conference days for "triangular conferences" with students and parents. No new time for triangular conferences is negotiated.
Fall 1996	Venture Capital Partnership grant is submitted by district. Lomond partners with three elementary schools and a middle school to extend the reform in mathematics to other schools in the district.
Fall 1996	"Saturday Scholars" Program begins for at-risk fourth-grade students in mathematics to prepare for the Ohio Fourth Grade Proficiency Test. Principal and teachers teach and plan lessons together.
Winter 1997	One Instructional Design Team is disbanded because of some members' continued resistance to the reform.
Spring 1997	Lomond Elementary School is selected to participate in a case study entitled "Transforming Learning Communities" (TLC). Another university mathematics educator joins forces with the Lomond faculty to assist with the case study.
Spring 1997	Second dissertation is written by a Lomond teacher about leadership of Lomond in the Venture Capital process — *The Value of Transformational Leadership in an Exemplary School District in Ohio: Examination of Conditions, Processes and Practices Associated with School Improvement* (Nader, 1997).
Spring 1997	Constructivism is challenged at school-board meetings by anti-tax group. Articles and memo are sent to the district officials and the board members, discrediting constructivist practice as a means to effectively teach mathematics. *Wall Street Journal* articles and the California State Board of Education attack the NCTM *Standards* and

	label the reform as "fuzzy math." Anti-tax group uses Fourth Grade Mathematics Proficiency scores as indicators of student achievement.
Spring 1997	Venture Capital Partnership grant awarded to Shaker Heights City Schools. Total amount: $25,000.
Summer 1997	*Snapshots* is revised. Teacher-leaders recommend to principals to disband IDTs and continue reform with only educators committed to instructional reform.
Summer 1997	Some teachers request transfers. Their requests are not accepted by other Shaker principals.
Summer 1997	Data collection for the TLC case study begins.
Fall 1997	Revision of *Snapshots I* is implemented. Principals reorganize reform efforts around a teacher-leadership team. Team initially includes 12 kindergarten-through fourth teachers and three first-year teachers. Leadership team begins taking active role in decision making about the reform and mentoring new colleagues.
Fall 1997	Substitute shortage impacts reform and Lomond's professional-development efforts.
Fall 1997	Teacher-leader team meets monthly with principals, secondary mathematics teacher, and university mathematics educator to build an instructional and assessment framework in mathematics.
Fall 1997	Authentic assessment system in mathematics and language arts is initiated. Student folders contain students' performance in mathematics (*Snapshots*), writing, reading running record, and a self-portrait. Work is saved for five years.
Fall 1997	Teacher-leaders hampered by time constraints. Expanded mathematics curriculum and a constructivist model of instruction require more time. Time factor documented in *Prisoners of Time* (National Education Commission on Time and Learning, 1994). District requires one "triangular" conference for each child.
Fall 1997	Decision made to create proficiency-type objective, multiple-choice quizzes for third-grade students. Tensions emerge over the philosophical consistency of this approach. Teacher-leaders feel this is a back-to-basics strategy.
Fall 1997	After-school tutoring for first-through-fourth grade students begins. "Saturday Scholars" continue to meet.
Summer 1998	Proficiency "report cards" put increasing pressure on the entire school system. Shaker Heights City Schools is not designated as "effective" on the state report card. *Snapshots* revised. Tuition-free summer school for at-risk incoming fourth graders starts at Lomond to improve fourth-grade proficiency scores.

Fall 1998 District kindergarten-through-fourth teachers implement authentic assessment system in language arts. Students' work saved from kindergarten through sixth grade. District distributes Mathematics Critical Objectives, which target skills in proficiency test.

Fall 1998 Third dissertation written by Lomond teacher. Dissertation examines and compares the achievement of African-American students in a traditional and constructivist model of mathematics instruction (Martin, in press). TLC case study completed.

Research Landscape

"Reform is a task whose complexity should not be underestimated" (Secada, 1992, p. 404). Many of the intricacies of school reform remain unknown. Little is known about how educators experience and lead complex change in an organizational culture which has historically resisted and stifled major change (Dewey, 1933; Fullan, 1993; Giroux, 1981; Goodlad, 1990). Even less is known about how educators implement a philosophical shift contrary to the current organizational culture. It remains uncertain what kinds of teacher knowledge are necessary to support major instructional change. Given the diversity and complexity of teachers' belief systems, little is known about how leaders communicate a reform agenda that changes traditional beliefs and practices.

The rationale for instructional reform in mathematics was clearly documented in 1989 by the NCTM and the NRC; however, how to lead this kind of reform and what impact such an epistemological shift would have on school change was unclear. Additionally, the literature did not anticipate how individuals within the organization would construe this change when traditional beliefs and practices were confronted with a different paradigm. It remained unclear how some educators may succeed in initiating and implementing major change. Therefore, the purpose of this case study is, to investigate the complex and dynamic nature of mathematics reform in Lomond Elementary School (kindergarten through fourth grade) where both principals and teachers are leading and implementing major instructional change. The primary research questions of this investigation are: (1) What triggers major school change? (2) What influence does instructional reform have on school change? (3) How does mathematics instructional reform evolve at Lomond school? (4) What leadership strategies are needed to push the reform forward? and (5) What internal and external complexities surround school change?

School change at Lomond Elementary School appears to be influenced by a major shift in epistemology. It is a shift that pulls away from dominant educational practices rooted in behaviorism toward practices reflective of constructivism. Constructivist learning theory, encouraged and supported by the NCTM (1989, 1991, 1995) and other research recommendations (American Association for the Advancement of Science [AAAS], 1989; NRC, 1989; National Science Teachers Association [NSTA], 1996), may be responsible for changes beyond mathematics instruction at the school.

The case study attempts to capture the nature of this change process through the following multiple sources: individual voices of key participants, dissenting voices, outside observers, descriptions of classroom instruction and classroom settings, student reflections, and student work. By seeing the combination of these key components, the reader may understand the complex and dynamic nature of the culture in this school.

Capturing and describing school change in a public school is challenging, because change is a complex phenomenon involving many key players — educators, students, parents, and the public — on several stages: local, state, national, and international. Therefore, what follows are snapshots of events and situations that unfolded within the intimate setting of one elementary school during a mathematics instructional reform project.

To build a clear picture of school change, chapters are organized around several themes. Chapter Two, *Constructivism in the Classroom*, describes the salient features of constructivist theory and the kind of changes constructivism has led to in mathematics instruction and assessment at Lomond. Gradual changes in assessment and instruction are portrayed through several vignettes. Each vignette demonstrates the range of instructional practice within mathematics classrooms and chronicles the kind of changes happening in many, but not all, Lomond classrooms. Chapter Three, *Impact of Reform on Roles and Relationships*, explores the various strategies used by the school principals and teacher-leaders to implement NCTM *Standards* and the impact these strategies had on existing sociopolitical norms and school structure. The chapter attempts to capture key leadership decisions and strategies that facilitated, sustained, and incubated the change process. Chapter Three also discusses some of the tensions that emerged as a result of the instructional reform. It begins with background information about the two principals who have played significant roles in the change story of the school. Then, the dialectical relationship between tensions and reform is discussed.

Chapter Four, *Emergence of a Critical Mass,* describes the many dimensions of school change. It begins with the changes in the structure of instruction and assessment made by principals and teacher-leaders. It then discusses what leadership decisions were made to sustain and nurture the climate of school for change. Finally, it shares the emergence of a critical mass of teachers necessary to keep the reform alive within the constant climate of disequilibrium and flux.

Chapter Five, *Complexity of School Change,* discusses the challenges the teacher-leaders and principals face when altering existing instructional practices and school culture. The chapter examines the complexity of educational reform and connects the change story of Lomond Elementary School to current research on the challenge of restructuring schools.

Chapter Two

Constructivism Evolving in the Classroom

To understand the impact of constructivism on mathematics instruction, it is necessary to describe how constructivism differs from behavioristic practices that dominate traditional mathematics classrooms.

Constructivist theory and practice include several elements beyond the theory and practices of behaviorism. It is not always a simple replacement of traditional "feed in" and "feed out," question-and-answer teaching. Instead, constructivist teaching in mathematics envisions a need for students to know basic skills in addition to a need to understand and apply key mathematical ideas. The constructivist teaching-learning environment attempts to develop knowledge and understanding through oral dialogue, diagrams/illustrations, concrete materials, mathematical models, reading, and writing. Constructivist educators believe that students remember and understand ideas through experience in relevant contexts.

There is little research on how to implement major instructional reform in mathematics or how to lead a paradigmatic shift in schools. Likewise, there is no consensus and few models of teaching practices that reflect constructivism (Simon, 1995). This lack of research places the educators and change agents at Lomond in a vulnerable and precarious situation. They exist in unfamiliar territory within the familiar landscape of a traditional school district. Therefore, telling the story of the mathematics reform and the educators leading it, the dilemmas and conflicts they encounter, the strategies they create, the decisions that they make, and how they choose to communicate about change to others may contribute to an understanding of the multiple dimensions of school change. A portrait of evolving change is painted through five classroom vignettes. Each vignette demonstrates the kind of changes occurring in mathematics instruction, within educators' thinking and within the sociopolitical norms of the school.

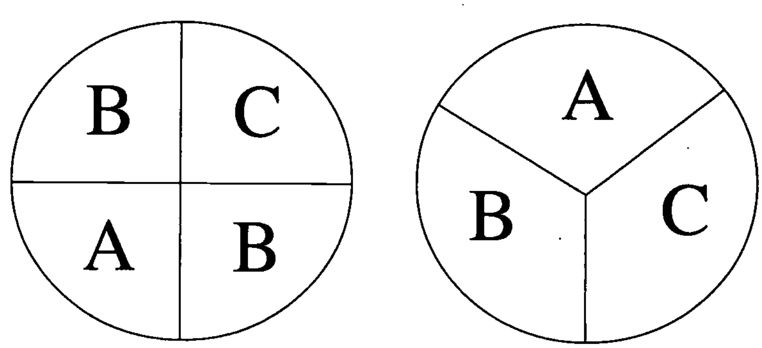
Vignette I: Principal as Teacher

The following vignette is an attempt to provide the readers with a glimpse of the role played by school leaders in their effort to both demonstrate discover what the reform involves.

[Setting: Seven fourth-grade students, from three different classrooms, are randomly selected by Lynn Cowen, the assistant principal, from the Lomond After School Childcare Program. The students eagerly enter the fourth-grade classroom, where some visiting graduate students are waiting. The children are happy to talk about mathematics for the visitors. The children enjoy working with the assistant principal, because she often teaches mathematics in their classrooms. Students quickly sit in a circle at the back of the room. One student immediately distances himself from the circle and leans against the radiator.]

Lynn: [The assistant principal poses the problem]:You are a contestant in the "Big Spinner Game." To win the game, the tip of the needle must land on the letter "B." Which of these two spinners would you select to win this game? [In the middle of the circle is a large 18" x 24" tablet of newsprint. She draws two large circles. One circle is divided into thirds. Each section is labeled "A," "B," or "C." The second circle is divided into fourths. Two of the sections are labeled "B," and the remaining sections are each labeled "A" or "C."

Figure 1. The Big Spinner Game.



Lynn: John, are you feeling all right?

[John is sitting outside the circle.]

John: Yeah.

Lynn: Why don't you join us? Or are you more comfortable over there?

John: I'm more comfortable over here. I'm just kind of tired.

Lynn: OK, but don't get burned by the radiator.

John: I won't.

Lynn: Now, here's the situation. You are at a carnival. One game at the carnival is a game where you can win a television-VCR if the needle of the spinner lands on the letter B. Landing on the letter B wins the TV-VCR. The rules of the game are simple. Before you play the game, you have to choose which spinner to use. You get a choice of spinners. Everybody understand so far?

Students: Yes.

Lynn: What do you think my question is about this problem?

Sally: Which spinner would we choose to make sure we would win on just one spin.

Lynn: That's right. Let me write your question on the paper. [Lynn writes the question.] OK. Now, just to make sure we all understand the problem, who can retell the problem? How about you, Ted? Now, everybody listen to make sure this is how you see the situation. Make sure important information isn't left out.

Ted: Well, we're at the carnival, and we want this TV set —

John: — and VCR combination! [Students giggle.]

Ted: Yeah, right. At this game we have to select a spinner to use. Landing on the letter B wins the game.

John: You have to do it the first time — no second chances at spinning.

Ted: Yes, only one spin.

Lynn: Is that how everybody understands the problem?

Students: Yes.

Lynn: OK, which spinner is best to use for this game?

[Students are silent and thoughtful.]

Lynn: Yes! I hear thoughts, smell brain cells burning. What's the problem here?

Alice: It isn't easy. It's tricky.

Bonnie: Yeah, you repeated the B in the circle with the fourths.

John: [now a little closer to the circle] The parts aren't the same size, either.

Lynn: What were you expecting, a "no-brainer" activity from me?

Students: NO!

John: [now lying on the floor within the circle] I would take this spinner [pointing to the spinner divided into fourths].

Bonnie: No, you shouldn't take that one. The sections are smaller than the ones on this spinner [pointing to the spinner divided into thirds].

Alice: But there are more Bs on this spinner.

John: Yeah, more Bs means more chance to win.

Bonnie: But you are counting Bs, you aren't looking at the part. One-third is bigger than one-fourth.

John: But there are more Bs here. See, one-fourth and one-fourth is two-fourths.

Ted: No, that's not two-fourths, it's one-half.

[Students pause and have a short discussion among themselves]

Lynn: Um, two-fourths, one-half, which is it?

John: It's two-fourths, because the spinner is divided into four equal parts. Two of those equal parts have Bs on them. Two-fourths B. [John, now sitting up, folds arms across chest.]

Bonnie: [quietly] I think it is the same, John. You can say two-fourths or one-half B. It's the same. Look. Here's one-half of the circle [tracing one-half of the circle with her finger]. Now here's two-fourths [tracing sections of circle again]. Two-fourths and two-fourths equal one whole circle.

Aaron: [who has been listening intently] Either spinner will win.

Lynn: What do you mean?

Aaron: Three-fourths needs one-fourth to be a whole. And two-thirds needs one-third to be a whole. Since they both need just one piece to be a whole, they must be equal and either spinner will win the game.

[At this time students are quietly puzzled. The graduate students lean forward on their chairs to better hear students' responses. They seem surprised by the dialogue.]

John: I don't know about that.

Lynn: I don't know, either. You folks have me most confused. I am going to have to think about this. I never thought about it this way. I think we will have to continue this discussion sometime tomorrow. [This is her way of ending lessons when she is unsure about how the students are thinking and how she needs to continue the instruction.]

After the elementary students leave the classroom, the assistant principal and the graduate students discuss mathematics instruction and the students' reasoning and problem-solving abilities. (For brevity, GS refers to graduate student.)

GS-1: Why did you stop the lesson? Was it because of the time constraints?

Lynn: No. I stopped the lesson because I was confused, and I didn't want to rush in and try to "fix their thinking" until I really knew my own. Basically, they surprised me. They pulled me away from how I had intended the lesson to go, and by doing that they made it richer — we both learned. That's pretty exciting stuff!

GS-2: How were you thinking about the problem at first?

Lynn: Well, I wanted to do something with probability, the likelihood of an event happening. Games at carnivals are within their experience. Then I always try to do the "unexpected." The lesson could have been just thirds and fourths. I then could have labeled each part with a letter. A through C for the thirds and A through D for the fourths. But that is not problematic enough. Why not "push the envelope" and find what they really can do? So, I "rig" the problem — and [laughing] I end up getting into "waters" where I am unsure, and they teach me a thing or two.

GS-3: What caused you to invent this method of teaching?

Lynn: I don't think we invented anything. This just kind of makes sense. As you could perhaps see, this "method" incorporates lots of communication and learning styles. Although I didn't use concrete materials here, the students have had lots of "hands-on" experiences with spinners, dice, etc. I began using math dialogues as a way to convince teachers that what we teach is not necessarily how the children construct meaning. It is very powerful for teachers to hear how students think about things. Teachers easily see where the misunderstandings are and can then create lessons to facilitate better understanding. When I model in our classrooms, teachers get the picture of what this constructivism looks like in practice. Just reading about it didn't do the trick. I just love to see teachers' expressions when they hear how students interpret teacher instruction!

Later, Roland Pourdavood, the university researcher, requested his graduate students to critique in writing what they observed.

GS-4: I was especially glad to see the short demonstration with the small group of students. The original goal of the lesson was not the direction the lesson actually took. What was important to me was the interaction between Lynn and the students. She let the students' comments guide the direction of the lesson. It was obvious to me that these students are comfortable and confident enough to share their opinions freely. I observed the questioning technique and how Lynn tried to understand the students' understandings. She gave the students the opportunity to explain what they believed in addition to how and why they believed it. There was dialogue not only among the students, but also between Lynn and the students.

GS-5: Although I realize when I return to my classroom as a teacher I may not be given the encouragement to duplicate exactly what I saw at Lomond, I will certainly try to incorporate as much as I can.

GS-6: The presentations [other Lomond teachers spoke to the group about their instruction] seem to keep returning to the same key factors. First it involved the construction of mathematical ideas through the students' daily life experiences. These new constructions, the teachers stressed, are facilitated by the dialoguing that takes place between teacher and student. This interaction appears to be pivotal for this program and, at the same time, it is also important to other areas of the curriculum. This method is very child-centered, unlike the traditional teacher-centered approach.

GS-7: We [teachers] should not assume we know how children think and understand ... Teachers should not tell students ideas, it is their job to guide and facilitate the learning that will enable the students to finally make the connection on their own.

GS-8: I will admit that it was so rewarding and helpful to see how this problem solving really works with children. Watching those children get so involved with the discussion and process involved in solving the problem about chance made all the difference to me. I could really see their thinking process in answering questions.

GS-9: Personally, I wish I could have learned mathematics in this manner. As a teaching community, we should try to implement such methods in our classrooms using information that is interesting and familiar to the children; building upon it can create richer learning experience than what comes from the book.

GS-10: The problem is that we do not truly listen to children's voices. When we take time to listen and follow the children's lead, we can find that children think differently from one another and differently from the way an adult thinks ... The key to the lesson was listening to the children and following their lead. Something like that is difficult to write up in a lesson plan.

Vignette II: First-Grade Classroom

The second vignette describes the transition away from existing instruction, where textbooks and commercial materials dominate teacher-centered instruction, toward teacher-designed lessons that engage students in learning.

[Setting: First-grade students, sitting at long tables, listen to a mathematics story "invented" by their teacher.]

T: [Teacher is holding a Florida travel brochure brought in by a student.] A long time ago I was in Florida and visited Lake Obeechobee. And living in Lake Obeechobee was a huge alligator named Old Chopper. Old Chopper got his name because he ate motor boats and everything in the motor boats, except the blades of the propeller, which he used to clean his teeth after dinner. [Students laugh.]

S-1: Did he even eat the people in the boat?

T: Of course he ate them. Old Chopper especially likes people, 'cause he was angry that they were driving their boats on his property!

[The students watch as their teacher begins to illustrate the story on the blackboard. The picture shows a cartoon-like alligator, smiling broadly, and several motor boats with propellers boating on the lake. Students murmur to each other about the picture.]

T: So, I would like you to tell me: how many days it will take Old Chopper to eat all the boats in the bay?

[The class is silent, then several students speak out in rapid succession.]

S-2: How many boats are in the bay?

S-3: How many does Old Chopper eat each day?

T: Oh, so you're telling me you need a little more information? Well, let me consult my book on Old Chopper. [Teacher walks over to his desk and retrieves the travel brochure.] It says here that Old Chopper in Lake Okachoobee eats two boats at breakfast, two at lunch, and two at dinner. It also says that, on a good day, there might be as many as 80 boats in Old Chopper's lake.

S: Oooo, that's a big number.

T: [Teacher hands out tubs of manipulatives to each table.] Now, you can use these if you want, or you can choose other manipulatives to work with. If you need scrap paper, you know where it is. Does everyone understand what they are to find out?

Class: Yes.

[Teacher then circulates among the students asking some students to retell the problem before they begin to solve it. At one table, a pair of students are having difficulty counting out the manipulatives: They don't know what number is after 77.]

T: Why don't you guys look at the tagboard hundreds chart in the front of the room? Maybe that will help you.

[At another table, the students are stymied because, according to their solution, there is a remainder of boats.]

S (all): Some boats are left over. Old Chopper won't get to eat them all. He will have to go another day, we think. But not a whole day, maybe just a part of a day, like just enough for breakfast. Maybe half a day.

T: What do you mean?

S-1: Old Chopper won't have six boats to eat the next day. He only has a few boats, not six. So, I think that he will just have enough to eat for breakfast.

S-2: He might just have one boat for lunch instead of two.

T: Math doesn't always end up just right, does it? I like your thinking. Make sure you share your ideas with the class when we tell our strategies.

[After about 30 minutes, the teacher refocuses the students to discuss process and solution. Not all the students have been successful at solving the problem, and the teacher makes the decision to stop the lesson.]

T: I think we may have to solve this problem as a class. I noticed some of you are still working, but I haven't had time to figure this out myself. So I would like all of you to help me and tell me what you did. What was the first thing?

S-4: We counted out 80.

T: And then what did you do?

S-4: We put them in groups of six.

T: Six? [Teacher looks at blackboard illustration.] I don't see six in this problem. Where did you get six?

S-7: Chopper eats two for breakfast, two for lunch, two for dinner. That's two, plus two, plus two — that's six.

T: Oh, I see now. Three twos are six. Six boats each day. Wow! That's pretty tough on the tummy. Am I finished? Is six the answer?

Class: No.

T: What next, then?

Class: You have to find out how many days it took him to eat all the boats.

S-1: Thirteen.

S-8: Fourteen.

T: Wait a minute. I hear two different answers. Let's see which one is right.

[Teacher calls on a student. Another student's hand goes up.]

T: Yes?

S-2: Don't we have gym today?

T: [Teacher glances at the clock.] Oh, my gosh, we forgot gym. Get on your gym shoes. Keep your math at your desk. We'll finish when we get back.

In the preceding vignette, the teacher-designed problem captured students' interest and was rich in mathematical content. However, the intent of the teacher was to direct students along a pre-determined instructional route toward a final solution. Few instructional digressions occurred, and few student comments perturbed the teacher's knowledge of mathematics.

Vignette III: Fourth-Grade Mathematics Tutoring Session

The following vignette describes a conversation between students and two teachers about time. The intent of the lesson was to investigate what students already knew about time and to use their understandings to create lessons. The students were required to dialogue with each other and to explain and defend their ideas. The unanticipated result was a perturbation of teachers' understandings when students revealed their experiences.

[Setting: Fifteen "at-risk" mathematics students regularly attend the "Saturday Scholars" program at Lomond to prepare them for the Ohio Fourth Grade Proficiency Test. The students are sitting in a circle, on the floor, with the two teachers. Both teachers plan lessons for this program. In this situation, the teacher-leader (designated as TL) was modeling a lesson for her mentee (designated as T). Each student has a small, yellow plastic clock.]

TL: So, what do you know about time?

S-1: There's 24 hours in a day. Seven days in a week. Thirty or 31 days in a month. Four weeks in a month. Twelve months in a year.

TL: Anything else that needs to be added? Anybody know other things about time?

S-2: He left out 10 years in a decade.

S-1: Oh, yeah. And 100 years in a century. Thousand years in a — I forget.

TL: Anyone know?

[Students, thinking, are silent.]

TL: Well, I'm not sure, either. So, let's go on. What about this 30 or 31 days in a month? Why those numbers?

S-2: I think it has something to do with the earth or sun.

S-3: Yeah, it does. Um, let me see if I remember. It's how long it takes the earth to spin around.

S-4: No, that's the time for a day — one complete spin — 12 hours of day, facing the sun, 12 hours of night, facing away from the sun equals one complete day. But I can't remember about months. Maybe it has something to do with orbit around the sun.

S-5: Yeah, it has to do with orbit. Like where in the orbit the earth is.

S-6: Yeah, whether it is close or far from the sun.

S-5: It never gets close to the sun or it would burn up!

S-7: But it has to get close sometimes because we have summer and winter.

[Students are silent.]

TL: Hum, I don't know about this orbit. Let's go back to one complete spin. Does everyone agree that one day is measured when earth spins completely around one time?

Students: Yes.

TL: And that one full day is measured in hours?

Students: Yes.

TL: And that one spin takes 24 hours?

S-8: Not always.

TL: Oh, tell me when it doesn't take 24 hours?

S-8: Well, sometimes it goes faster. Sometimes it goes slower. But most of the time it takes 24 hours.

T: [Teacher leans forward and responds to student's comment.] That's not right! Where did you get that idea?

TL: Let him finish. I am interested. There is fast time and slow time?

S-8: Yes.

TL: I never thought about time this way. What does everyone else think?

S-1: Time does go fast and slow. Like waiting for Christmas or my birthday, time goes slow. Vacations go fast.

S-4: Yeah, I agree with you. Sometimes school goes fast and slow, especially lunch!

[Students laugh and smile to show agreement.]

TL: So, let me understand. You're saying that time is measured in hours, but sometimes those hours go fast or slow. So what about the earth's spin? Does the earth spin faster one day than another?

[Students think about the question.]

S-1: I think it spins slower in spring and summer than in winter and fall because the days are longer in spring and summer.

S-3: Yeah, that's right. My bedtime is 8:30. In the summer I hate going to bed when it is still light outside. In the winter, it is dark. That's because of fast and slow time.

TL: Well, if hours go fast and slow, do months also go fast and slow?

S-9: Yes, look at the months, some are 30 days, some are 31, and February is 28 days.

S-10: Sometimes it is 29 days.

S-9: Yeah, but only once every four years.

TL: This is most interesting. Fast and slow hours, days, and now months. I guess I always thought that an hour was always the same length of time — it didn't speed up or slow down. Now you are telling me that February is "fast" for most of the time, but every fourth year, February slows down and takes one extra day.

S-11: That's right, because that's "Leap Year." One extra day is added to the calendar. Instead of 365 days, there's 366 days that year.

TL: What makes this happen?

S-12: Probably the earth just stands still in its orbit.

TL: Who then "jump starts" earth moving again?

[Students are quiet.]

Later that day, after school, the two teachers meet to debrief the lesson and to plan instruction.

T: Why did you let them continue with that nonsense about "fast and slow" time? Where did they get that notion? It was so painful to listen to. Eventually, you should have told them how wrong they were.

TL: I couldn't tell them they were wrong, because I didn't have a way to change their thinking that would make any more sense to them. I didn't find the situation "painful." I found it intriguing how they built such elaborate misunderstandings to make sense of time. Now, we've got to figure out how to dismantle these perceptions and help them construct it differently. Before I do this, I have to revisit science concepts and make sure I understand orbits, rotations, revolutions, and seasons. Then, I suggest we create experiences that let them see that time is a constant. Erasing misunderstandings will probably be more difficult than building new ones.

Several factors may have contributed to gradually changing teacher beliefs and classroom social norms. The first factor was listening to students' explanations of their solutions. The second factor that provoked change in teachers' beliefs and social norms was when teachers observed their students learning mathematics with the university consultant. During these observations, teachers saw the range of student understandings in mathematics. Student voice began to impact teachers' instruction as teachers began to actively listen to students and ask, How do you know that? Student voice seemed to be a catalyst for expanding teachers' understanding of mathematics. Student voice also impacted the kinds of learning experiences teachers created. It was not uncommon for students to share with the teacher everyday experiences such as earning money babysitting or buying a CD, and for the teacher incorporate these experiences and the students' names into a problem for the class to solve.

Understanding students' thinking and dialogues between teachers is fundamental to instructional reform in mathematics (Pourdavood & Fleener, 1998). The above professional dialogue reveals the importance of communication and illustrates a variety of new roles for teachers: teacher as staff developer, teacher as adult learner, teacher as instructional designer, teacher as intellectual. This vignette may also suggest a key role for students in instructional design and students as catalysts for teacher learning.

Vignette IV: Third-Grade Classroom

The next vignette describes a third-grade classroom in which teacher, as facilitator and learner, supports students' ideas, understandings, and mathematical creations. The intended subject of the lesson was elapsed time and rate. What developed was a reinventing/creation of calculating time.

[Setting: Third-graders are assembled in a circle on the floor. Some students are leaning against large bean bag chairs or pillows. The teacher sits on a small chair next to a "dry-erase" easel. The students each hold a paper that contains their solution to a mathematics problem that is written on chart paper on the bulletin board. Illustrations, diagrams, words, and numbers have been used to show student strategies and thinking. The students are to share their solutions to the problem, which reads as follows]:

> Susan, Twanda, and Deontae babysit. They each charge $6.75 an hour. Susan baby-sat from 1:30 until 3:00. Twanda baby-sat from 6:15 until 9:15. Deontae baby-sat from 7:20 until 9:50. If they wanted to buy two pizzas to share, and each pizza cost $14.00, would they have enough money to buy the two pizzas? Defend your thinking and solution with illustrations, words, numbers, and symbols.

T: OK, who would like to start us off with your method of attacking this problem?

S-1: I would.

T: OK, begin. Why don't you come to the easel and illustrate how you thought about the problem?

S-1: [Student takes marker and begins drawing three stick people. She labels each with the letters: "S," "T," and "D." Then she mimics a "teacher voice"]: OK, class. This is Susan, Twanda, and Deontae. [Students laugh and are attentive.] Susan worked one and a half hours — 1:30 to 3:00. [Student writes "1:30" under the figure of Susan.

[Several students look puzzled; they whisper to neighbor. Teacher also looks puzzled.]

T: Shh, let her finish her thinking.

S-1: Twanda works three hours — 6:15 to 7:15 is one hour. 7:15 to 8:15 is another hour. And 8:15 to 9:15 is another hour. [Counting on fingers] One, two, three hours. [Underneath Twanda, she writes, "3:00." Again, the students are puzzled.]

S-3: That's not how you write three hours.

T: Let her finish, please; then you can ask her about her method.

S-1: And Deontae works — um. — This was harder to figure out. 7:20 to 9:20 is two hours. And 9:20 to 9:50 is 30 minutes. That makes two hours and 30 minutes. [She writes "2:30" under Deontae.]

T: So now what did you do?

S-1: I added up all their times.

T: Show us how you did that.

[Student writes on the easel]:

$$\begin{array}{r} 2{:}30 \\ 3{:}00 \\ \underline{+\ 1{:}30} \\ 1{:}00 \\ \underline{+\ 6{:}00} \\ 7{:}00 \end{array}\ \text{hours}$$

T: Wow! Does everyone see how [S-1] invented a way to add time? Tell us about the "1:00" in your problem?

S-1: Well, I know that 30 minutes and 30 minutes is 60 minutes, and 60 minutes is one more hour, so I just added one more to my hour column.

T: What kind of comments do you have for [S-1] about her method and solution?

S-3: You really confused me at first. I thought you were writing down the time it was and not the hours. I was wondering, can you add time this way?

T: I don't know, what do you think? Are there examples where her method might not work? [Teacher puts hand on S-1's shoulder.] I would like to thank you for showing me a way to add time that I have never thought about. You really taught me something new today. Thank you. [S-l sits down.]

Ss: We're not finished with the problem, yet.

T: No, we're not. Let's finish it after snack. I want Dr. [Larry] Svec [principal] and Dr. Cowen [assistant principal] to see this strategy before we erase it.

In the above vignette, the role of teacher as learner is reinforced through the support of individual student understanding and creation. In the vignette, a student's risk taking is interwoven with the teacher's risk taking. Teacher risk taking is twofold: (1) the teacher did not know exactly the direction of the dialogue or how to explain the student's reinvention when calculating elapsed time, and (2) the teacher was comfortable following the rhythm of the uncertainty and the emerging nature of the dialogue. In none of the previous vignettes did the mathematics lessons come to closure. Several of the vignettes show the need for additional time to put constructivist learning theory into practice. Building student understanding of key mathematical concepts seems to require more time than is currently allocated in school schedules.

Vignette V: Second-Grade Classroom

The following vignette describes classroom interactions in which the social norms are established and controlled by the teacher and in which only correct responses are validated. There are a few classrooms where this kind of interaction and communication are observed.

[Setting: Most of these second-grade students are seated at desks, which are arranged in clusters and rows. Some students, however, are seated in rows; these students, according to the teacher, "can't handle" working collaboratively. Each student has a small cardboard clock assembled from the back of the mathematics workbook. Student workbooks are open to pages that require the students to read the time on clock faces. The class is reviewing skills in preparation for the assignment.]

T: [Teacher holds up a large demonstration clock.] Now, who can tell me what a clock does?

S-1: It tells time.

T: Good; who can tell me what is time? [Teacher moves clock hands to show 1:00.] For example, what time does the clock show now?

S-2: One o'clock.

T: That's right. [Clock hands are reset to 6:00.] Now set your clock to look like mine. Hold up your clocks so I can see them. What time is it?

S-3: Twelve-thirty.

T: No, let me see your clock. Oh, I see your mistake. You mixed up the hands of the clock. Change them. [Student complies.] Now, do you see your mistake?

S-3: Yes.

T: Good. [Changes time again to read 1:45.] OK, now everybody have your clocks look like this. What time is it?

S-4: One forty-five.

T: That's very good! Forty-five minutes after the hour is hard to figure out sometimes. I am really proud of you. Now here's what I want you to do. In your math book on page 74, you will see that there are many clock faces showing different times during the day. Look carefully at the clock, make sure you look at the hour hand first, then go to the minute hand and count by fives from the 12 to see how many minutes past the hour you are. If you need help, use your own clock, or come see me and I will help you. [Student hand goes up.] Yes, [S-3]?

S-3: Is the time day or night?

T: Oh, that's a good question. Remember how we talked about a clock shows only how many hours?

S-5: Twenty-four.

T: No, on the clock, what is the larger number?

S-5: Twelve.

T: Right, so the clock only shows 12 hours at one time. So what did we discover together about the hands of the clock?

S-6: The hands have to go around two times.

T: Yes. [Teacher models with the clock.] See how the hands have to travel all around the clock to count off 24 hours in one whole day. But how will you know if the time in your workbook is daytime or nighttime?

S-7: In the corner there is a sun or a moon. That tells you daytime or nighttime.

T: Good observation. Now does everyone understand what they are to do on page 74?

[Several students together say, "Yes."]

As this vignette suggests, the interaction in the above classroom setting was more listening and valuing right answers instead of facilitating and creating learning opportunities for both students and teacher to make sense of the concepts inherent in time. Also, the use of manipulatives conveyed the mechanical understanding of the time, where children could interpret time as clock-reading.

As demonstrated by the vignettes, the range of instructional changes in Lomond classrooms are diverse and dependent on teacher understanding, involvement, and commitment to the reform process. Questions remain about how and why these changes occurred. What strategies were necessary to promote teacher change? What leadership decisions nurtured risk taking and encouraged teacher change? What impact did leadership decisions have on the nature of the reform and the culture of the school? And finally, how and why did a critical mass of teachers emerge to lead and sustain the reform in their classrooms?

Chapter Three

Impact of Reform on Roles and Relationships

The previous chapter attempted to create a thick description of the differing instructional practices in mathematics. This chapter attempts to capture key leadership decisions and strategies that facilitated, sustained, and incubated the change process. The chapter also discusses some of the tensions that emerged as a result of the instructional reform.

The chapter begins with background information about the two principals who have played significant roles in the change story of the school. Then, the dialectical relationship between tensions and reform is discussed. For the purpose of clarity, those teachers who support the reform are called "teacher-leaders"; teachers who do not support the reform are called "Lomond educators"; and "Lomond teachers" refers to all teachers in the school.

Role of Principals in School Reform

The process of instructional reform in mathematics and school change at Lomond cannot be fully understood without a closer look at the role that two principals — Larry Svec and Lynn Cowen — have played over the last 10 years. Larry, Lomond's principal, earned his Ed.D. in school administration/curriculum and instruction. In the late 1970s and early 1980s, Larry was assistant principal in the junior high school. At the junior high school, he became aware of how the culture and structure of schools present problems for student learning. He saw that the structure of school often severely limited children's time to learn and stifled their intuition, creativity, and imagination. He wondered if there was an alternative way to help all children learn.

In 1986, in the reorganization of elementary schools in the district, Larry was appointed principal of Lomond. It was one of the pivotal events at Lomond. His reform agendas in language arts (whole language) and mathematics (NCTM Standards, 1989) gave him some alternative ways to see how children could learn, read, write, and do mathematics. His role changed when he abandoned his position as a traditional administrator/manager and stepped into the role of principal as teacher, action-researcher, and learner.

In 1990, Larry and a handful of teachers, including Lynn, who was Lomond's staff assistant, tried to implement the NCTM Standards recommendations in Lomond classrooms. The process of instructional reform in mathematics was nonlinear and uncertain, as if they were stepping into unknown territory. They were making their "roads by walking" (Horton & Freire, 1990).

Another pivotal event in the life of Lomond appeared when Lynn, a former second-grade teacher, became staff assistant and then assistant principal. Similarities and differences between these two principals created situations for more perturbation and disequilibrium among the school community. Lynn's research interest and her dissertation on the implementation of the NCTM reform at Lomond brought these two leaders much closer together to tackle the reform agenda. With the help and support of some teachers, they wrote grants and invited in university and secondary school teachers as consultants to push the reform forward. The secondary teachers joined consultants in elementary mathematics classrooms, where the consultants played the role of teachers and interacted with students modeling mathematical ideas for Lomond teachers. Principals and some teachers also engaged in conversation and dialogue with consultants in order to better understand mathematical ideas.

In the first few years of the 1990s, teachers' participation in reform was voluntary. Everyone seemed happy, and the school appeared to be in harmony.

> *This building came together as a product of reorganization. I was the only one from [name of the school] assigned here. I found the staff very open, full of laughter, and a lot of fun . . . Dr. Svec [Larry, the principal] would visit from time to time. It was great when he came to my room, because he would see my children doing a lot of hands-on activities. I felt that I was a real leader.* – A Lomond educator

However, disequilibrium and tensions emerged in the mid-1990s when the instructional reform became mandatory. Pushing the reform from voluntary to mandatory impacted the climate of the school and the roles and relationships among the teachers and principals. The process of change shifted the Lomond staff from a state of equilibrium or near-equilibrium (within the structure of status quo) to a state where teachers became quite sensitive to, and occasionally tense about, any changes that occurred. The possibility of division among the staff was real.

> *I took a sabbatical for half of the year, three years ago, to observe split classes. I even volunteered to take a kindergarten-through-one split. I was in this building every other day ,modeling teaching. I did school visits all over and taught classes. It was a wonderful time for me. But it was when Venture Capital was starting, and I was not a part of it. I came back and was not included the next year, either. Last year we all got together in "break-out*

groups," and I don't know how much my input is valued. I don't philosophically even agree with everything that is being done. I believe in change for a reason, not just for change's sake. I guess that is where I differ.... At our individual meetings, I was listened to, but when my team leader would go to the other meetings, I didn't get the impression that what I was saying was really valued. I've been given the impression that there is a right way to teach math and a wrong way to teach math. And I was told last year that I wasn't teaching math right. To be told, with my background that I could not attend NCTM because I wasn't teaching math right was a shock! . . . I worry that children who are visual learners are being left out the loop. Enlarging the print is not enough. When I posed this problem, I was yelled at and told that if I just enlarge the print that would take care of it.... The important thing is that we respect everyone. I don't think that's happened. – A Lomond educator

Tensions between "haves," or those who supported the reform (namely principals and teacher leaders), and "have-nots" (those who for whatever reasons did not support the reform) signaled the deeper layers of conflict and challenges for the principals.

It is important to note the significant role the principals played in fostering the emergence of a critical mass of teachers. On the one hand, by supporting, mentoring, and nurturing teachers who were willing to participate and contribute to the local school reform, they gradually built a critical mass of teachers. Without this critical mass, the progress of reform would have been slowed or even stalled. On the other hand, with a systematic plan to isolate or ignore other voices, they created an unhappy family, tensions, resistance, and mistrust among a small group of teachers.

Evolution of School Change Through Instructional Reform

To facilitate the reform process, the school principals devised ways to expand teachers' content knowledge through on-site staff-development sessions, during which teachers handled new instructional materials (manipulatives) and were taught within a constructivist climate. Instructors for these sessions were selected for their ability to model constructivist practice in mathematics. The intent of this initiative was to demonstrate how mathematics could be taught to all children in an active, interactive way. Through the process of professional development and negotiated meaning, many teachers began to realize that mathematics could be learned through active engagement and dialogue, something that was completely absent from their personal experiences with mathematics instruction.

I love teaching math, because it is so different from the way I learned it. But it has also been the hardest thing for me, because I learned it in a very traditional setting. That is not how we teach it, because it is not what is best for children.... To create something new everyday takes a lot of energy and a lot of work. – A Lomond teacher-leader

Early in the reform effort, few textbooks existed that addressed the NCTM *Standards*' recommendations. Teachers and principals researched and collaborated with university and secondary mathematics educators to better understand mathematics content and to develop their own pedagogy grounded in constructivism. "It is a continuing process which is shared by the community of learners. Whenever I leave this building, I leave feeling better than I came in," (says Ray Skitzki, the collaborating secondary mathematics educator). Within this collaborative structure, teachers invented and restructured a streamlined mathematics curriculum that focused on main mathematical ideas such as unit, unitized systems, zero to infinity, change, chance, dimensionality, and location in space and the key processes of combining, comparing, and partitioning. It became necessary for the Lomond teachers to develop their own materials and write mathematics lessons aligned with this restructured mathematics curriculum that valued student problem solving, reasoning, communication, modeling, and student experiences.

The integral connection between mathematics instruction and assessment emerged through students' writing, modeling, and discussions. Whereas students eagerly participated and enjoyed mathematics, the teachers were left with the dilemma of how to assess student performance authentically. There existed no models of how to evaluate student writings and illustrations in mathematics. Adding to this situation was a district report card that assessed student behaviors and skills. Lomond teachers, therefore, began to develop an authentic assessment system that was congruent to the NCTM (1995) recommendations and would provide a better means of assessing student growth. A team of elementary and secondary educators developed a series of performance tasks that would (1) capture student growth over time, (2) act as instructional targets for teachers, (3) encourage reading in the context of mathematics, and (4) assess the application of skills and what students understood about mathematics. The performance tasks in grades one through four were given to students in the fall, winter and spring (see Appendix B for a sample of kindergarten-through-fourth-grade performance tasks).

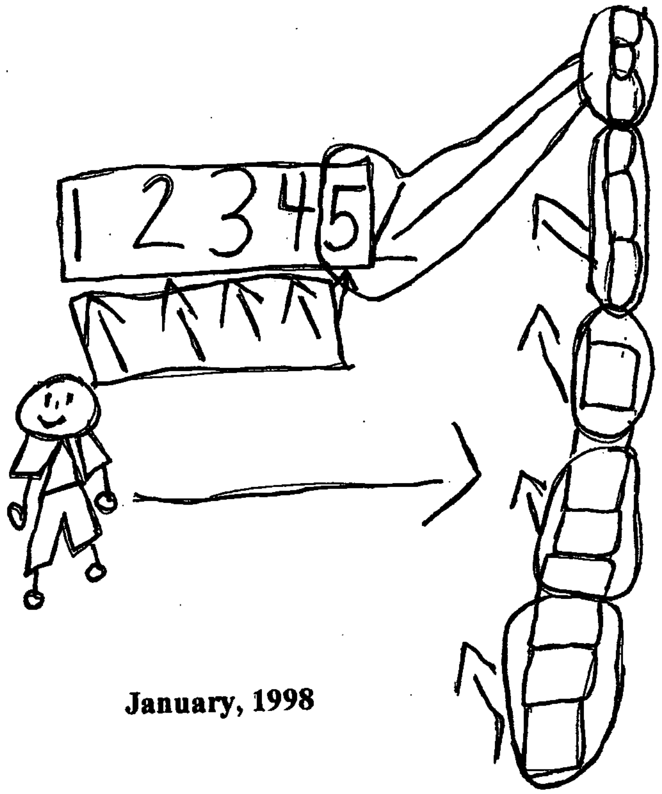
Figures 2 to 4 are exemplars of kindergarten performance tasks that were given in the winter and spring of 1998 to all kindergarten students. Each of the following samples contains the winter and spring performance tasks from the same student. These performance tasks represent relevant, contextual problems for students. The problems were open-ended, since students were encouraged to solve the problem in a way that made sense to them. Also, when viewing the difference between the first attempt and second attempt at solving the problem, the students could invent different ways to solve the same problem. In addition, comparing student solutions reveals a gradual growth in communication, reasonableness, and sophistication and a movement away from concrete to more abstract representations, which may signal student cognitive growth. The figures show evidence of multiple ways students were encouraged to demonstrate their problem-solving abilities through drawing, writing, and computing.

Figure 2. Kindergarten Performance Task: Length and Time.

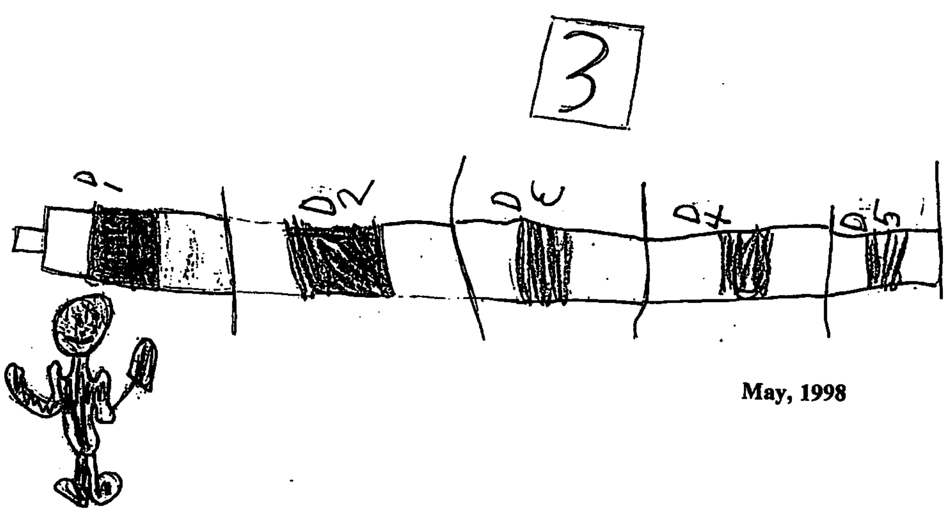
The beanstalk that Jack planted really grew fast. After 5 days it had grown 15 unifix cubes tall. How much did it grow each day if it grew the same amount every day?

My Responses

Use pictures, words, and numbers.



January, 1998



May, 1998

Figure 3. Kindergarten Performance Task: Length and Time.

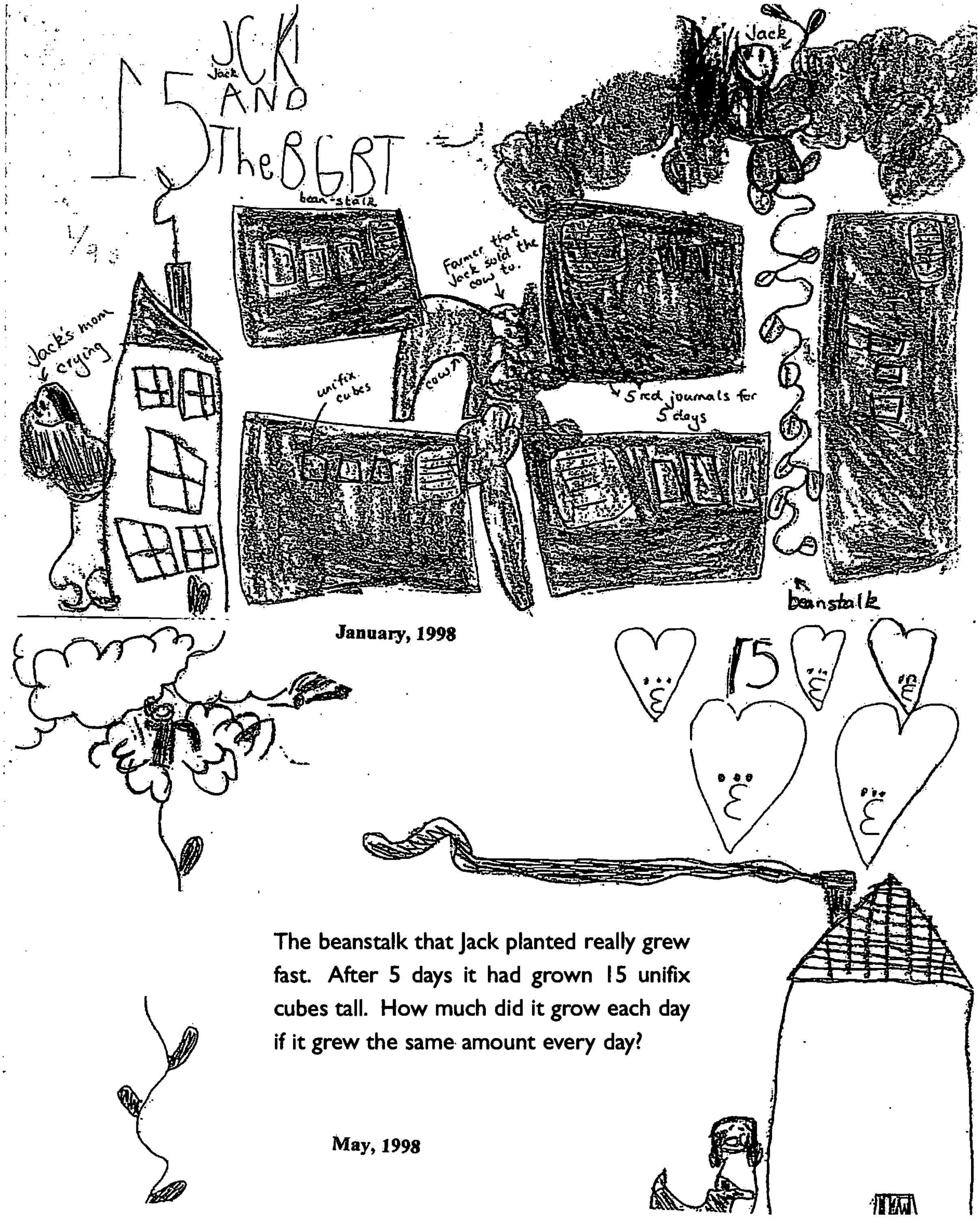


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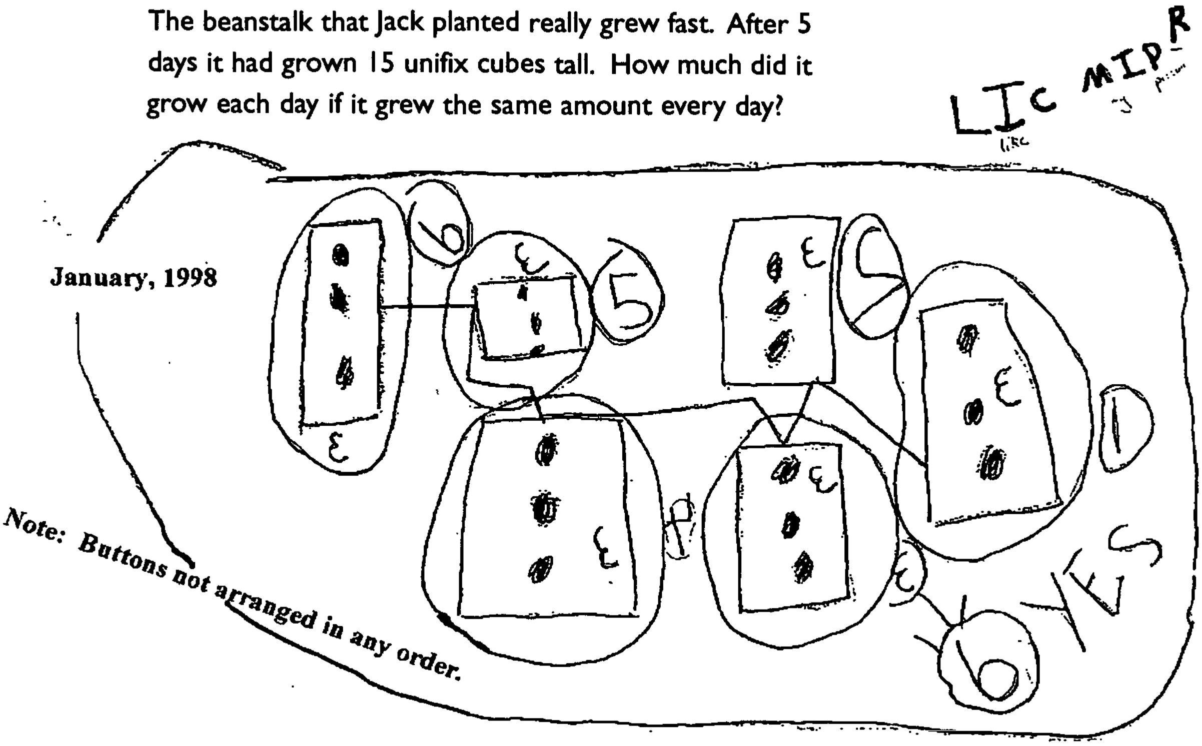
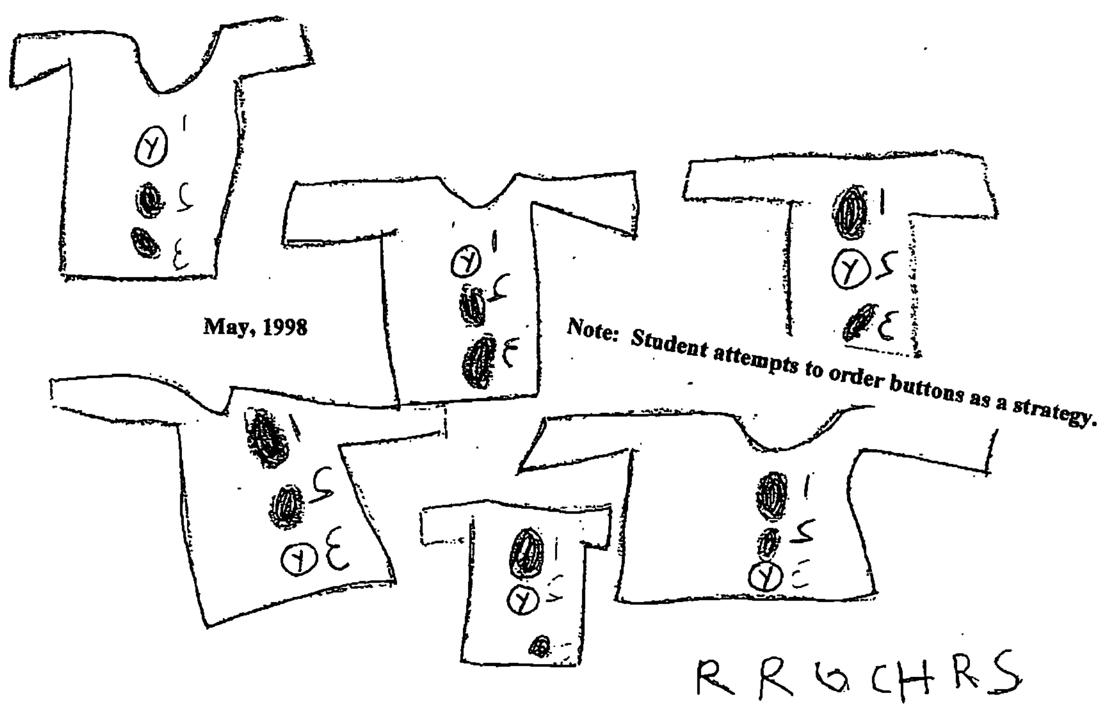
Figure 4: Kindergarten Performance Task: Chance

The beanstalk that Jack planted really grew fast. After 5 days it had grown 15 unifix cubes tall. How much did it grow each day if it grew the same amount every day?



January, 1998

Note: Buttons not arranged in any order.



May, 1998

Note: Student attempts to order buttons as a strategy.

Teachers as writers and creators of instruction and assessment were an important factor in Lomond's reform. "Teacher" emerged as an "action-researcher," creating instructional experiences based on classroom interactions. These experiences were shared, revised, and collected into documents for the entire staff.

> *These math problems need revision this summer. But then, I guess we will always be rewriting them each year. Who would have guessed?* – Lomond teacher-leader

The instructional and epistemological change was not a smooth process. It created perturbations and disequilibrium within the school community.

> *When this reform started, I did not agree with it because I did not understand it. I had to have a conversion. I had to come to a place to understand it* – Lomond teacher-leader.

As the reform evolved, many educators struggled to make mathematics relevant to students' personal experiences, which placed teachers in a role to which they were unaccustomed. Furthermore, the reform, in some cases, targeted teachers' limited understanding of mathematics; this added to their insecurities and resistance.

> *I would fight with Larry all the time. Every time he came into the room, I would be using the math book and doing drills. I just couldn't accept that I couldn't do [math reform]. It caused some tension and a breakdown of communication. He couldn't convince me and I couldn't see anything else. I didn't try, because I didn't believe in it.* – A Lomond teacher-leader

However, some teachers did discard their dependency on mathematics textbooks and weekly predetermined lesson plans. Instead, they wrote mathematics instruction and designed performance tasks that would monitor students' growth. Limiting the reliance on prescribed instruction and textbook-driven curriculum by teachers added to the disequilibrium in the school. A once cohesive and congenial staff was becoming polarized over differing perspectives about mathematics instruction and the role of teachers in the reform.

> *I enjoy the autonomy I have here. At other schools, lesson plans eliminate "teachable moments." I would have to stop and rethink. I usually have a general direction [ideas and processes], and I don't write lesson plans more than three days in advance. I change them so often.* – A Lomond teacher-leader

Despite the emerging instability and differing perspectives, some teacher-leaders continued to design lessons that targeted the performance tasks. They were encouraged to write lessons and have students solve problems within the context of several unitized systems, such as time, money, weight, capacity, and temperature. Working within these unitized systems, students would understand the relationships and patterns within and between the systems such as the relationship between time and distance (speed/rate).

Figure 5 is a fourth-grade lesson designed by a teacher-leader to target the fourth-grade performance task on measurement and statistics. Figure 6 a student solution to the assignment. The student's solution mirrors similar instruction in kindergarten (Figures 2-4). Illustrations, writing, and calculations are valued in solutions. There is no prescribed procedure for solving the non-routine problem. The problem situation is relevant and reflective of student experiences. What emerged within the student work was the addition of reflective writing as a way for students to justify their thinking and solutions. This was not evident in all the kindergarten papers except for one sentence in Figure 3 in which the student stated: "I LIC MI PR" (translation: "I like my picture").

> *I think people tend to think, you just come up with all these ideas. People don't realize that an idea just doesn't pop into your head. You are thinking about [mathematical ideas and processes] all the time.* – Lomond teacher-leader

Figure 5: Exploring Length in the Classroom

Name ______________________

Date ______________________

Instructions for students:

Take measurements of objects in our classroom. Choose a unit of measure. Record, collect, organize and display your measurement data of these objects. Write, draw and computer your findings.

I. Measure the circumference of the heads of all the students in this class. Select a unit of measure. Collect, record, organize and display the data in a meaningful way. Then, measure other parts of the body. Collect, record, organize and display this data also.

II. Make comparisons between student head sizes and other parts of the body. What did you find out?

III. Compare head size to size of baseball caps for all the students in our class. Organize and display your findings to show:

a. head size and cap size

b. the largest head and cap size

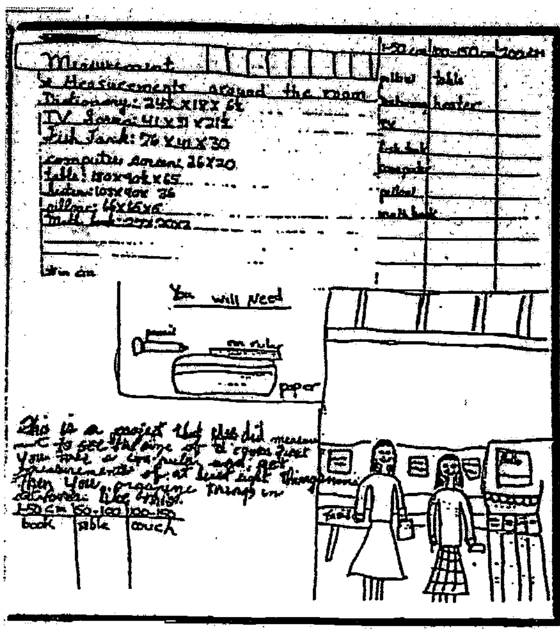
c. the smallest head and cap size

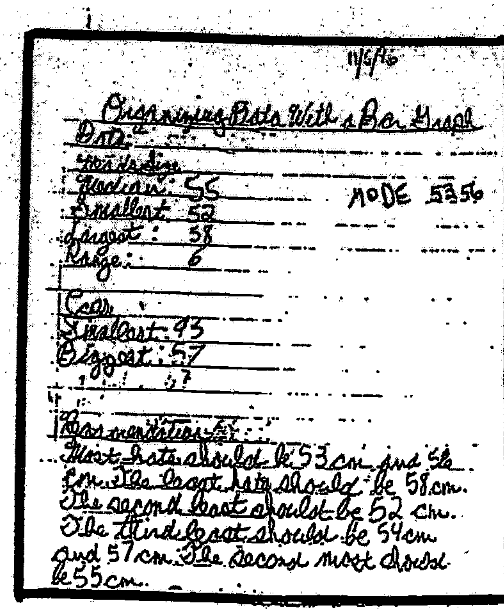
d. the range between the largest and the smallest size heads and caps

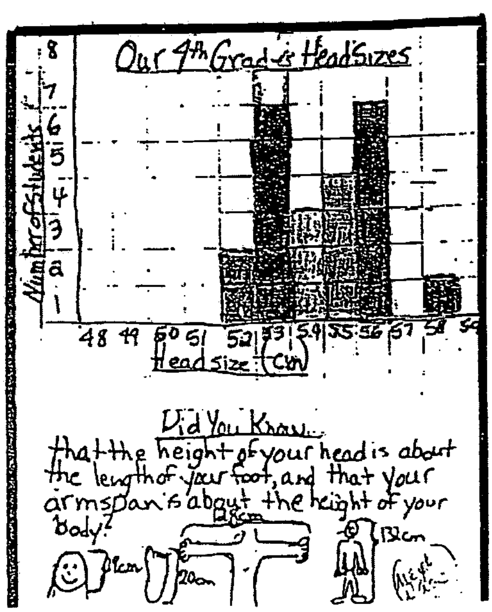
e. the median number for head and cap sizes

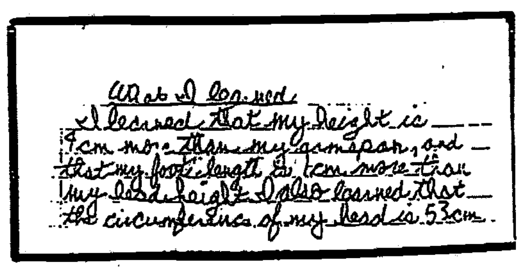
IV. Self-evaluation: On the back of your finished solution, include our class rubric and use the scale 1-4. [Rubric categories mutually agreed upon by the fourth-grade class were: description of problem, methods used to solve problem (pictures, words, numbers), neat and colorful work, organization, accuracy, and justifying solution (reasoning)].

Figure 6. Student Solutions for Measurement Assignment.









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There is a reflexive relationship between instruction and assessment. There is also a close relationship between a teacher's and students' mathematical empowerment, whereby both the teacher and students create the need for instruction and assess the worth of instruction (Grundy, 1987). This relationship seems to produce a synergy among members of the classroom community, where student voices echo their confidence in doing sophisticated mathematics in a risk-free environment.

> *The problem is we don't know how to translate 7/16 into cents. The price per share means how much we paid and how much the stock went up. We do this every Wednesday . . .* – A fourth-grade student

> *She is going to teach long division . . . she lets us use calculators, because my past teachers never let me use a calculator and the problems were really hard. My parents are really glad she lets us use calculators, because they say it is required for high school and college math.* – A fourth-grade student

The interdependence of mathematics curriculum, instruction, and assessment can be observed when teachers assess student learning. Assessment of students provided teacher-leaders information about students' instructional needs. Teacher-leaders collected this information during classroom mathematics dialogues and when they reviewed student assignments. Figure 6 represents a cross-section of students' various understandings and abilities on the first attempt at a first-grade performance task. Four samples of student solutions were selected by the teacher-leader. The samples represent differing student abilities. The range of samples assisted the teacher in designing lessons that would help students understand the concept of area. The figure contains teacher's self-evaluation of his/her instruction. Furthermore, the comments in "beginning steps" and "next focus" show the teacher's instructional decision making. When this instructional-assessment model was presented at a teacher-leaders' meeting, reactions were varied. Some teacher-leaders applauded this method of instructional decision making and evaluation. Others felt the approach was too time-consuming.

Other initiatives created more disequilibrium especially when the traditional role of principal as manager and administrator evolved into principal as teacher, learner, instructional designer, and staff developer. At Lomond, the principals actively participated in implementing the reform within classrooms to communicate a constructivist model with the teachers. Both principals taught and modeled mathematics lessons with students. Some teachers were surprised by principals modeling instruction in the classrooms. These teachers rarely welcomed principals to teach in their class or to teach with them. They seemed uncomfortable when principals planned and taught mathematics and had an opportunity to see what children were learning in the classroom.

Revisiting the Story of Tensions and Reform

Lomond Elementary School cannot be understood as a learning community being transformed without accounting for various tensions that emerged during a shift in epistemology. The following describes what occurred when instructional change necessitated a change in beliefs and practices, which challenged members of the school community.

Tensions began emerging when the focus of mathematics instruction changed from a more mechanical and instrumental approach to one that emphasized relational and conceptual understanding of mathematics. As it was stated earlier in this chapter, Lomond teachers were initially a happy family when all staff participated in a hands-on approach to mathematics instruction. They took pride in being the first school in Shaker Heights to actively address the NCTM *Standards* (1989) report. A team of eight kindergarten-through-fourth-grade teachers drafted lessons (*Umbrellas*; Cowen et al., 1990) that incorporated concrete materials (manipulatives) into mathematics instruction. These lessons were not conceptually focused nor did they reflect constructivism. Lessons were intended to broaden the scope of mathematics content, to adopt new materials, and to make mathematics fun. Initially, Lomond teachers were surprised by students' and parents' enthusiasm for this interactive approach to mathematics instruction.

Teacher: Lynn, the kids won't let me put away the math materials. My lesson has gone for over 60 minutes. They really like math. They cheer when I tell them its time for math. But what am I supposed to do about all the other subjects?

Lynn: How about integrating them in your language arts program . . . but for heaven's sake, don't stop the math. If they like it, maybe they will learn it!

Although this "new" mathematics instruction engaged children, teachers, and some parents, the change was mechanical: Adopting new materials and exploring new content areas such as pattern and probability did not change teachers' traditional beliefs and practices. Over time, teachers had seen an endless array of new materials and new curriculum pass through their classrooms. Teachers were used to hands-on lessons to supplement textbook-driven instruction. "You know, Lynn, this isn't new. We've done the 'hands-on gig' before," said a Lomond teacher.

The reform took a different direction when some kindergarten-through-fourth-grade Lomond teachers, in collaboration with secondary and university mathematics educators, reinvented mathematics instruction around key ideas and processes within a relevant context. Focusing on main ideas was seen by some teachers as different. Some teachers also interpreted the reform as not following the district curriculum and seemed to view the instructional changes as replacing other mathematics programs in the district. Tensions emerged as some teachers' instructional practices began to look different from practices in other classrooms and teachers began to write lessons to supplement the district curriculum.

Many Lomond teachers were unfamiliar with instruction that was emergent, flexible, and responsive to students — one that was based on reasoning, problem solving, communication, and mathematical representation. Some teachers resisted the focus on problem solving or mathematics problem solving as enrichment activities for students.

> *I just think that the pendulum is swinging too far. Do you have to throw out everything that we have done in the past in the name of "change"? I think we need to hold on to some of the things we have done. I am behind problem solving. I was one of the first people to do problem solving.* – A Lomond educator

Other events were happening simultaneously. A different elementary mathematics textbook was adopted by the school district. Several Lomond teachers served on the adoption committee. They recommended to the Lomond principal that he should not order the new textbooks. In their opinion, the books had little substance; they felt that what had been written at Lomond was far more consistent with the NCTM *Standards* (1989).

> *Larry, don't order the textbooks! We write better than that. You know how the books were adopted? Heath and Company [textbook company] came in with balloons and gave all the members of the adoption committee Heath candy bars. Big PR push. See if the money we save from ordering textbooks could be used to buy some math materials.* – A Lomond teacher-leader

Larry followed the recommendation. No textbooks were ordered for Lomond students. Central office administrators refused Larry's request to use textbook funds for additional mathematics materials.

> *. . . I mentioned the fact that reliance on a textbook was not what Larry valued, and some members of the faculty picked up on that. There was a pressure to develop materials in mathematics [at Lomond] and not rely on the textbook. For some of the teachers who are not as far along in the process, that [decision] created some concerns.* – A Shaker Schools educator

Generally, Larry's decision was seen as not giving books to teachers and, therefore, crippling teachers' abilities to provide quality mathematical instruction. Some teachers, union members, and administrators questioned Larry's maverick decision to not order the adopted district mathematics textbook.

Some tensions among the staff began when school principals valued teachers as instructional designers and encouraged them to submit proposals that would build instructional models of mathematics. Individual proposals were funded and supported with Venture Capital money. Teachers ordered their own materials and equipment necessary to develop their instructional model. Classrooms began to look different. Most Lomond teachers, as well as the secondary teachers, submitted proposals. Some teachers who had been active participants and supporters of the reform refused to submit individual proposals. "I'm not going to have my instructional model judged by anyone. No one is going to tell me whether I've met my goals or not," said a Lomond educator.

When school principals encouraged the majority of the teachers to take risks and build new instructional models, factionalism grew. Most teachers who refused to submit proposals continued to implement mathematics reform in their classroom but attended few professional inservices at the school. Distancing themselves from the reform and others involved in it limited opportunities for them to communicate their ideas about the reform in a professional setting. Few of the non-participants opposed the substance of the reform. Most non-participants held similar views about learning and teaching mathematics for young children, and they understood the need for change in mathematics teaching. What seemed to cause the dissension was more the disruption of sociopolitical norms — not treating everyone the same, not doing business as usual. The drift away from sameness and homogeneity grew more obvious as the non-participants noticed other colleagues aggressively taking risks, making change, and tackling the reform agenda.

The principals at Lomond decided to move the reform forward by concentrating on mathematical ideas and processes, and depending on those teachers within the school who were willing to take risks and push the reform agenda ahead. The leadership was seen as discriminating between "haves" and "have-nots". Leadership decisions were viewed by some teachers as creating an elite group in the building. This was contrary to the notion of happy family. Larry was aware of the potential risks of this factionalism.

> *We do want to change behavior and instructional practices, and to me that gets to be a challenge. Lomond will have to learn to find ways to start to work with people, and certainly they have done that to a certain extent. However, they need to make everybody feel that they have something to contribute so that the teachers begin to change their instructional practice. Therefore, it is something internal, something that motivates them, and not that they feel it is dictated by the organization. That makes a difference.* – A Shaker Schools educator

It was becoming increasingly more apparent that the changes were not only about new methods, but also about a different way of thinking about teaching and learning mathematics. In this epistemological shift, Lomond teachers were asked to work with a university mathematics educator to develop a model of constructivist practice congruent with the NCTM recommendations. At first, teachers were unwilling to change their instructional practices away from a teacher-centered model. Teachers seemed uncomfortable with being asked to explain how and what students were learning. Teachers were more familiar with tests and completed workbook pages to document what students learned. They felt that if a lesson was presented clearly and carefully, then students would learn. Their reluctance to try a different instructional model forced the assistant principal to create a way in which teachers could see the value of actively listening to student voices and the impact of asking different kinds of questions such as, "How do you know that?" The following is the assistant principal's reflection on this process.

> *The university mathematics educator and I were really frustrated. Here I had teachers who were not even interested in a constructivist model of mathematics. So, I told the pro-*

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fessor to model a lesson reflective of constructivism for fourth-grade teachers. The professor sat on the floor with the students and me in a large circle. Teachers sat in chairs behind the students. The lesson was supposed to be about data analysis. Students were to put data on a pie graph. I can't remember much of the details, but some place in the lesson, she, the professor, made a right angle with a large wooden compass. She asked the children, "What is this?" The students responded, "A right angle." She then asked, "How do you know it is a right angle?" One student answered, "Because my teacher told me so." Some teachers paid attention to this unfortunate explanation. I don't really know what made me reach across, take the right angle and reverse it, and ask the question again, "What is this angle?" Without any hesitation, a student said, "Oh, its a left angle." Now, the teachers began to sit straight up in their chair. They knew I would take advantage of this situation to prove a point. So, I continued to ask the students some more questions. I flipped the "left angle" upside down. "Now, what angle is this angle?" A girl answered, "Oh, that's easy, it is a left-upside-down angle." Not one student challenged any of these responses. By this time, the teachers were out of their chairs. One teacher who had her hands positioned to choke one of her students said, "There's no such thing as a left-upside-down angle. I taught you this stuff two weeks ago." I looked up at her and said, "You taught it. They understood it differently." That was the beginning of our journey into constructivism as a way to find out how children come to know. It also was a beginning where some teachers began to change how they questioned students. I could never have planned such a powerful experience for teachers. From that day on, Larry and I went into classrooms to model constructivist lessons for teachers. – Lynn Cowen, Assistant Principal

Interacting with students in classrooms and providing teachers opportunities to see that their instruction might be inadequate created some additional tensions. Some teachers were uncomfortable having administrators ask how they knew what their students had learned. Also, they did not like principals conducting lessons in their classrooms, where the results of their instruction were echoed in student voices and performance. Defending existing instructional practices in mathematics against the new instructional model reflective of constructivism required some teachers to read research. As the reform became more research-based and as professional dialogue centered on epistemology and pedagogy, resistance to the reform by a few became more obvious.

The next year brought additional changes. There was a need to provide a coherent instructional framework for teachers and to strengthen the link between instruction and assessment. During the summer (1996), an instructional design team, composed of 12 elementary and secondary educators, took on the task of creating an assessment model that captured cognitive growth in mathematical understanding. The outcome of their effort was a series of performance tasks about dimensionality, money, time, and probability (see Appendix B). These performance tasks reflected end-of-year learning expectations and were to be used by teachers as instructional targets for their instructional decision making.

The format of these performance tasks was different in that each performance task was to be administered three times, in the fall, winter, and spring (except in kindergarten, when they were given in winter and late spring) in order to capture a "snapshot" of student academic growth.

How the tasks were administered was standardized throughout the classrooms. Teachers were instructed to read, discuss, and even solve the performance tasks with their class. After the discussion, students were to present their own thinking and understanding on paper independently. All students were to build models, illustrate the models, and attach labels (words and numbers) to the models before using mathematical notation (equations, symbols, etc.). The intent was (1) to facilitate the teacher's ability to read what students knew about mathematics, and (2) to capitalize on young children's inventiveness and familiarity with illustrating.

Illustrating in mathematics meant that teachers had to model this for children. Some teachers were both unfamiliar and uncomfortable with drawing solutions and models in mathematics. This created disequilibrium among some staff members. Another source of tension was the idea of revisiting the same task three times during the year and stating the solution prior to independent performance.

Teacher 1: Let me see if I have this right. You want me to read the problem to the class; let them find the important information to solve the problem; then discuss possible ways to solve the problem; then solve the problem with models; and then send them back to their desks to solve the problem by themselves.

Lynn: Yes.

Teacher 1: They already know the answer.

Lynn: I don't think they all know the answer. They've heard the discussion, seen the model, but they all know it differently.

Teacher 1: But all they have to do is copy what we just all did on the floor together.

Lynn: Even if they copy the model, they have to convince you through their own words and pictures that they understood what was going on. You see, I am convinced that unless what you've done in class makes sense to their prior experiences and knowledge, they will not be able to convey that understanding on paper in pictures, words, symbols that convince you of what they actually understand.

Teacher 2: Well, what about the same problem three times during the year? They already know the answer. They will be bored. We never do the same thing three times a year.

Lynn: I know. Maybe the students will do the problem differently. Maybe they will look at their work in the early fall and see how it can be improved.

Teacher 2: They can look back at what they did in August?

Lynn: Yes.

Teacher 1: I don't believe this. I'm not going to let them do that until they've finished their second or third try. I don't want them to see their previous answers.

Tension was most acute at the kindergarten level, where changes such as more problem solving, dialogue, illustrating mathematics solutions in student mathematics journals, and revisiting key performance tasks were openly condemned, first at Lomond, and then at district kindergarten grade-level meetings. This instructional-assessment model was labeled as developmentally inappropriate. The general feeling among some of the teachers was that this new mathematics instruction was exposing children to mathematical ideas and problems that were too sophisticated and too frustrating for young children. Also, it was felt that young children could not physically remain inactive for the length of time required to discuss these performance tasks and problem-solving situations.

> *I worry about the developmental inappropriateness of some of the activities. Last year, some of the problems that were given had numbers that were far too big [20] for kindergarten . . . When you are giving the children language, you have to keep the number reasonable. The problems we were given had unreasonably large numbers. This bothered me, and I did not know how much my input was being listened to.* – A Lomond educator

Characterizing the reform as developmentally inappropriate disrupted the climate of the school. The label seemed to confuse some teachers, including two kindergarten teachers who were actively engaged in developing new instructional models in their classroom. To resolve this issue, the principals sought advice and research as to what was developmentally inappropriate mathematics instruction for elementary children. Professional opinions about the appropriateness of young children problem solving were solicited from professors, researchers, and teachers who came to visit Lomond classrooms. It was finally determined that this instructional model was not inappropriate. On the contrary, most educators were amazed at what the kindergarten students were able to accomplish. Many educators felt that problem solving in kindergarten may provide a good foundation for mathematics.

Both the debate and the search for additional information on this debate are ongoing. At a recent conference at which the case team described this debate, the following observation was made:

> *I find nothing inappropriate about your kindergarten performance tasks. The tasks are very appropriate for young children. We are finding that young children are capable of so much more in mathematics* – Constance Kamii, Psychology of Mathematics Education PME-NA Conference, October 31–November 3, 1998, in Raleigh, North Carolina

What may have been the underlying cause for this tension was not only changes in instruction and assessment practices but also a major structural change in the reform. Prior to the implementation of *Snapshots* (Cowen et al., 1996), participation in the reform was voluntary. Teachers had been encouraged to submit individual proposals for changing their instructional practice. A few teachers did not submit proposals, thereby excluding some students from the reform agenda, something the principals did not want to do. Consequently, the principals required that all Lomond teachers would use the *Snapshots* performance tasks. Some teachers did not like mandated participation and complained. To facilitate implementing *Snapshots*, all Lomond teachers and tutors were placed on one of four Instructional Design Teams (IDTs). These teams met for three hours twice each month during the school day. The IDTs were composed of kindergarten-through-fourth teachers. The teams de-emphasized the traditional grade-level structure and the role of grade-level chairpersons. Each team was led by two teacher-leaders. Some leaders were tenured; some were not. The selection of the teacher-leaders caused more tension. "I don't much like taking direction from non-tenured staff members," said a Lomond educator.

The dissension about instructional reform went to the heart of issues about power, status, and social identity within the school community. On the surface, teachers argued about how students learned mathematics, but in deeper layers, the changes perturbed the sociopolitical norms of the school. Some teachers were uncomfortable when grade levels were reorganized into cross-grade-level teams, causing some teachers to form new professional alliances.

The formation of IDTs was a challenge to some teachers' status in the school community. Originally, grade level chairpersons led grade-level teachers in meetings with principals. Their responsibility was to disseminate information, mentor new teachers, and collaborate with school administrators in planning school events. Principals often sought the opinions of grade-level chairpersons. Social relationships and status in the school were often tied to this grade-level structure.

The new structure of teacher-leader was different, however. It disregarded seniority and experience as a prerequisite for leadership. Sole reliance on grade-level chairpersons gradually changed to a reliance on teacher-leaders to make decisions and guide the reform. Factionalism began to emerge within the IDT meetings. This factionalism impacted communication within the school. Teacher-leaders and some members of IDTs were surprised at the intensity and persistence of some Lomond faculty in challenging and halting the reform process. In some cases, tensions among team members were so intense that some teachers requested transfer to another IDT. A few Lomond educators requested transfers to different schools. Continued tension impeded advancement of the reform. The teacher-leaders were frustrated in their efforts to dialogue about mathematics instruction and to advance the reform. At the end of the school year, many teacher-leaders recommended that the kindergarten-through-fourth IDTs be disbanded; they suggested one team consisting of only teachers willing to advance the reform agenda. This situation posed an interesting dilemma. The reform had been structured to include all teachers and all students. Some staff members had been uncomfortable with the reform disrupting the climate of the school. Including all teachers again in the reform had also been an attempt to address this concern. Some teacher-leaders and the principals determined that the tensions were not easily resolvable, would divert the reform, and limit its progress. Also, it was obvious that continuing the reform with only four-fifths of the teachers would further fuel tensions. The principals formed one large leadership team that included new teachers and their mentors. Excluding some members of the school community in one large leadership group added further tensions, resistance, and mistrust.

Chapter Four

Emergence of a Critical Mass

The way we are teaching now is a lot harder. Many people aren't ready. The knowledge of math that is required now is more difficult. There is an element of belief in what we are doing. You really have to believe it. People have to experience it in order to change their whole schema. – A Lomond teacher-leader

You know, I was thinking on my way to work this morning, how differently I teach now. You wouldn't believe how I used to teach. Before, I used to "sugar coat" the curriculum, make a big show, entertain the kids to keep them from being bored. I never thought about the substance of my lessons or if they helped students learn. I just assumed they did. But now, I listen to the kids before designing lessons. I am always thinking about how I can improve so the students will really learn. I feel so much more fulfilled than before. I could never teach that way again. – A Lomond teacher-leader

Changing the Structure of Instruction and Assessment

In many Lomond classrooms, the structure of mathematics instruction evolved away from a reliance on textbook, conventional activities, and computation-based assessment practices toward teacher-designed materials, problem-centered activities, and performance-based assessment practices that reflected problem solving, reasoning, communication, mathematical connections, and mathematical representation. The evolution of structural change in mathematics was supported by restructuring current mathematics curriculum away from skill-based and toward key mathematical ideas and processes.

Social norms of some classrooms also began to change. There were gradual shifts in what teachers valued within the context of mathematics instruction. There was a shift away from students remaining at desks, working independently, and toward the development of a small learning community, where teachers and students sat together on the floor and mutually constructed understandings. These changes encouraged and ignited changes in how mathematics was communicated in classrooms (Pourdavood & Fleener, 1997). Students and teachers often sat on the floor, with one set of manipulatives and a large tablet of paper, on which students and teachers drew their understandings and discussed a problem situation. These classrooms were characterized by (1) active listening and participation of all students, (2) valuing multiple solutions and procedures, (3) encouraging risk taking, (4) equally valuing diverse student experiences, and (5) seeing the individual student as a co-contributor to the instruction.

In some other classrooms, social norms seemed teacher-controlled. These classrooms appeared characterized by (1) linear communication between student and teacher whereby the teacher elicited and validated the correct answer, (2) emphasis on efficient and reliable algorithmic procedures, (3) limited support for student risk taking, and (4) formal classroom experiences that did not always value student's prior experiences and understandings. These differences were noticed by visitors, parents, and the principals when they taught lessons in classrooms.

The structure of assessment changed away from relying on uniform grade-level learning outcomes to rank and rate students, toward an authentic assessment system that emphasized individual student performance as a means to chart students' growth and set new learning goals. Teacher conferencing moved away from traditional 20-minute, teacher-parent conferencing about report card grades, toward portfolio assessment and student-led conferences where teachers, students, and parents collaborated to evaluate student performance, chart growth over time, and establish new learning objectives.

> *There has been a big improvement in math this year. She really had problems in math last year. But now I see her level of interest is very high in math and she is growing in problem solving. Before, she would say that she "hates math" but now, she likes it. She is more confident in her problem solving and reasoning.* – A fourth-grade parent

These "triangular conferences" required more than 20 minutes. Some Lomond teacher-leaders lobbied for more conference days and urged their union leaders to negotiate additional days into the new teachers' contract. Additionally, the teachers asked Larry to pressure the district administration to bring this issue to the bargaining table. When both union and management appeared not to be interested, some Lomond teachers took the initiative to extend conference days into time before and after school, and created evening conferences. Conflict arose over the issue of evening conferences as a substitute for daytime conferences. Central office administrators refused to hire substitutes for teachers during the day so that teachers could conduct late afternoon and evening conferences. Teachers could not use after-hour conferences as a substitute for conference or instructional days.

Limited time continued to plague the reform. Mathematics lessons at Lomond exceeded the state's mandated 45 minutes of daily instruction. Since mathematics instruction in many classrooms now incorporated problem solving and dialogue, the need to find more time became apparent. Extended time would be required for meaningful interactions between student and teacher. The master schedule for the school was restructured to keep students and teachers in classrooms for longer periods of time without interruptions.

Changes in the lunch schedule altered existing social interactions in the school. Historically, all district elementary teachers ate at the same time and instruction stopped. Lomond had three lunch periods in order to create larger blocks of instructional time in the classroom and more flexibility in scheduling special classes. The lunch schedule disrupted social relationships in the school. Teachers no longer had the opportunity to eat with the same colleagues each day of the week or with teachers in other schools. Having lunch periods at different times each day meant that Lomond teachers were in the lunchroom with different colleagues every day. Lunchtime changes were accepted by most teachers; a few seemed to enjoy the freedom away from the former routine.

> *You know, I was driving to school today and I began to think about the lunch schedule. It's kinda nice having lunch at a different time each day. It makes the days different, and I don't think that I am at a factory where the lunch whistle blows and everyone leaves.*
> – A Lomond teacher

Also, the structure of the school calendar year created two other dilemmas for the reform. First, the daily schedule did not provide enough time for meaningful instruction. It was clear that in order to expand mathematics curriculum and employ a different instructional model, the school day needed to be expanded. Second, as issues in the district arose over proficiency scores and student underachievement in mathematics, extra days were needed during the school year. It was evident that in order to adequately address student underachievement, at-risk students needed more time. This idea of an extended school day and year was not popular with most Lomond teachers. Few teachers recognized that they were prisoners of time and, instead, assumed that student achievement could be raised within the traditional time structure. The debate over more time produced the establishment of an after-school elementary tutoring program in each school and a tuition-free summer school at Lomond for incoming fourth graders.

Changing the Leadership Structure

Changes in organizational leadership began early at Lomond. In 1990, two events occurred that impacted the leadership of Lomond School. First, a public-private match grant proposal was accepted by the Ohio Department of Education. The grant proposed to change elementary mathematics instruction and align mathematics curriculum with the NCTM *Standards* (1989). Second, student enrollment at Lomond increased and a staff assistant was added for administrative support. In addition to other tasks, the staff assistant was to direct the grant process. Later, Lynn's role as staff assistant was changed to assistant principal. The addition of another administrator helped advance the reform.

Bringing her out of the classroom and giving her administrative responsibilities to direct and guide a major instructional effort was something elementary teachers weren't used to. Before, they were accustomed to developing relationships with just one principal. A sole principal in the building is an easy target. Teachers knew all too well that there is too much work for one principal. So teachers can easily go about their business and not worry whether the principal ever shows up in their room. When Lynn came on board, that changed. We suddenly were everywhere talking to teachers, and I was no longer an easy target. – Larry Svec, Principal

The principals' common interests in research and how children learn mathematics helped forge an effective partnership and impacted the nature of the reform. The principals frequently disseminated research articles to the teachers and parents. The articles triggered intellectual dialogues in meetings and hallways. "Luckily, I'm on their [Lomond] mailing list. I get all the journal articles and I read them," said Ray Skitzki, secondary mathematics educator.

Valuing research created the role of teacher as "action-researcher" and "writer." Reading journal articles encouraged some Lomond educators to implement the research and write about classroom instruction and the impact of the reform. Three dissertations were written by two Lomond teacher-leaders and the assistant principal. Two other dissertations are in progress. All these doctoral theses are about the changes happening at Lomond School. Also, one Lomond teacher has written a book about reform in language arts.

Teacher as "action-researcher" and "writer" evolved in other ways. Teachers sought out new ways and materials to improve their classroom instruction. They wrote mini-grants and lobbied the principal for additional school funds. In most cases, requests were supported. Teachers as action-researchers were expected to report on their projects during grade level meetings or staff meetings. Often, their activities were replicated in teachers' classrooms. These "action-researchers" became teacher-leaders.

Teacher as "instructional designer" was fundamental to professional development and adult learning. Early in the reform, it was clear that teachers reflected on what they knew about mathematics and connected it to how children learn mathematics. Teachers' writing instruction had a significant impact on staff-development programs. Inservices were specifically designed to expand teachers' content knowledge and pedagogy. The secondary educators worked closely with the principals to design staff-development sessions that would help teachers design instructional experiences.

Different structures were created to inform parents about the changes in mathematics instruction. Parent-Teacher Math Nights were designed and led by principals and teacher-leaders. These meetings communicated the reform to parents. In these meetings, parents actively engaged in building models, drawing, and writing about mathematics. Through these activities, parents began to see the differences between traditional and non-traditional mathematics instruction. Another purpose for these meetings was to demonstrate to parents how they might support and facilitate student learning at home.

Apart from the Parent-Teacher Math Night was an initiative undertaken by the principal to meet with a few parents to discuss the ideas and the rationale for this reform effort. His hope was to develop strong parental support among key members of the community and to further extend the level of communication. This group designed a schoolwide project entitled "Families Talking Math," where parents wrote problem-solving situations for children to take home and solve with adults. Solutions were signed by parents and returned to school and entered into a drawing, where students could receive a free book from the Parent-Teacher Organization (PTO) Book Nook. The group also purchased mathematics manipulatives and created a library check-out system for these materials so students could take them home.

Using outside educators and district secondary mathematics educators as consultants and staff developers ignited tensions among the school leadership, the teachers, and the consultants. Most Lomond teachers accepted the secondary mathematics educator as consultants and facilitators. These consultants were frequent visitors to Lomond classrooms and often conducted lessons with Lomond students. However, secondary educators' involvement at Lomond raised questions from their colleagues, particularly at the high school. "Why are you spending all that time at Lomond? What could be so interesting at an elementary school?" Ray Skitzki, secondary mathematics educator said his colleagues asked him. The implication was that he, as chairperson of the mathematics department, was spending too much time off-site and not attending to his responsibilities. During his time as chairperson, Ray devoted almost seven years to his on-site support of Lomond. In 1996, the department voted for a new chairperson.

Not carefully defining the role of consultant with one of the university professors led to unfortunate consequences. Territorial conflicts developed when the secondary and university educators had strong professional differences and when the university consultant attempted to extend the role of consultant into that of a decision maker.

Larry: Another complexity was the jealousy between the university consultant and Ray and Tim [middle mathematics chairperson]. They also had a little bit of a professional disagreement.

Ray: It wasn't a "little bit"; it was a lot.

Furthermore, the university consultant's attempt to communicate reform to parents during a PTO meeting failed and put pressure on the principal. Larry sought ways to continually communicate the reform to parents.

> *She tried to carry the discussion with the parents, and it almost exploded. She couldn't connect with the parents, and she did not have a good understanding of school reform and the sociopolitical dimensions of structural change. Her communication and conversation with parents failed. That was the point where I made two decisions . . . to calm the situation down.* – Larry Svec, Lomond Principal

The principal limited the consultant's role to interacting only with the teachers. He carefully monitored who and what was communicated to parents about the reform.

> *I began a parent group and I met with them every month, because I could not lose this reform process. And I told Lynn that I had to be the one to deal with the parents, and I saw to it. Gradually, I included some teacher-leaders in parent meetings about mathematics instruction.* – Larry Svec, Principal

Another event that signaled a decision to further limit the role of the consultant was when the assistant principal and the consultant disagreed on the direction of the reform. The consultant recommended limiting the involvement of the principals' participation in staff-development sessions. "She was saying that we include everyone and reduce the administrators' role in participating and guiding the reform," said the principal. The assistant principal did not like this recommendation, because it limited her opportunities to learn and write with teachers.

> *I explained to her why I didn't accept her plan. She just wouldn't accept my explanation and was very angry.... When I think about it now, it was probably a power struggle — a "Who's leading the ship?" scenario. Unfortunately, it had some dire consequences. Teachers were confused, and some were angry when we limited the responsibilities of the consultant, but it couldn't hold us up from going forward. Somehow, the teachers thought it was my job to make everyone happy and comfortable in this reform.* – Lynn Cowen, Assistant Principal

Limiting the consultant's role did confuse and anger some teachers. The relationship between the consultant and the assistant principal eroded. The erosion of this relationship, according to the principal, put the reform at risk and caused some Lomond teachers to support the consultant's perspective regarding exclusion of the principals from staff-development meetings.

> *. . . So I was watching all of this stuff happening. Lynn was getting frustrated; she had had a major disagreement with the consultant. The consultant was suggesting that the teachers needed to get away from principals' involvement. I didn't have a confrontation, so I tried to hold the reform together. Then the issue was about how to manage the leadership. I sensed that relationships were falling apart. Therefore, I wanted to keep the relationship with the consultant and kept that communication open . . . I was willing to compromise and work with her to keep the reform going . . . I kept talking, trying to reach a compromise.* – Larry Svec, Principal

This conflict, although disrupting, had positive aspects. It forged an awareness of the fragility of the reform and how vulnerable it was to personal interactions. It showed the importance of effective communication about roles and relationships within the school community. The conflict created a new initiative that gave teachers the space and time necessary to communicate. The principals placed teachers on kindergarten-through-fourth Instructional Design Teams and appointed teacher-leaders to lead them. The teacher-leaders met regularly with the principals to discuss and guide the reform.

Within this collaborative decision-making partnership, new roles began to emerge. Some teachers began to realize the importance of teacher leadership and the impact they could make to improve instruction. The teacher-leaders saw that by putting research into practice and developing instructional models, they could lead and model change for other teachers.

Conflict highlighted the importance of relationships and tolerance within the school. The principals and teacher-leaders communicated about the importance of ongoing dialogue and trust. However, the conflict also left some permanent scars on the school community. Relationships and trust among a few Lomond teachers and principals were damaged. Resistance to reform broadened the focus of reform from instructional changes to structural changes — changes in the existing rules, roles, and relationships in the school. A few teachers who did not agree with these changes started to work actively against the reform process.

Teacher Change

> *It's sad, you know. The reform has caused changes in each of us. We look and sound different than others. We no longer fit. The sad thing is that there is now nowhere for us to go in this profession except Lomond. I had a teacher tell me that he could never go back, even if it was mandated. He would shut the door and continue using this way of teaching.* – Lynn Cowen, Assistant Principal

Another factor emerging from the reform was the ongoing communication about pedagogy. Teachers began talking together about changing instruction and environments to accommodate new practices. Many teachers observed and then used constructivist theory during mathematics instruction. When teachers asked different types of questions, validated student experiences, and supported student risk taking, they saw the difference between what they taught and what students learned. This impacted some teachers personally.

> *It is hard to change people's minds. You couldn't change mine. It just so happened in my own pursuit, for my own reason, I came upon it and changed my mind* – A Lomond teacher-leader

However, the changes in mathematics instruction were not understood by some teachers. This lack of understanding led to intimidation and personal confrontations, where the teacher-leaders were perceived as "Larry's puppets." Interestingly, this reaction had positive results and helped mold a strong teacher-leader group that had to find ways to deal with resistance. Further, intimidation and confrontations served as indicators of how deeply embedded the change was.

> *Early on, we loaded up our wagon with manipulatives and pulled it by the "dragon at the gate." We got by because the dragon has seen "hands-on" stuff before, so we went through the gate. But once we started changing the beliefs and values to another paradigm, the dragon got angry and the fight was on. No one disturbs the "educational dragon."*
> – Lynn Cowen, Assistant Principal

The reform created controversy and personal conflict among the members of the school community. After several years, 20 percent of the Lomond teachers are still not actively engaged in reforming mathematics. Perhaps non-participation was not always related to the main ideas espoused by the reform. Instead, the reform may have inadvertently challenged existing rules, roles, and relationships. It may have disrupted Lomond's informal power structure and the school district's formal power structure. It may have perturbed the business-as-usual routine. Participating, then, in this instructional reform may have been too risky and/or not inviting for some teachers.

Nevertheless, most teachers began to see the connections and relationships in mathematics and expanded their content knowledge. They began to focus their instruction on mathematical ideas and processes. Even though this focus was questioned by some senior teachers, many teachers continued to build instructional models. Parents seemed to support these constructivist environments. As teachers actively listened to students' voices, they were more and more surprised at how children made sense of mathematics and how often their own sense of mathematics was inadequate. Simple questions such as, "How do you know that?" and, "Does everyone agree with this?" became an effective way for the teachers to see that what was taught was not necessarily what students learned. Through these simple questions, the teachers saw the importance of connecting their instruction to students' experience. As more attention was given to student voices, gradual changes emerged. Individual change was not easy.

> *It is hard to change. I was in tears a lot. I would go home not knowing if what I was doing was right. I was afraid that at the end of the year the kids would not understand. It is scary to take risks. You have to say, "Look, it is working, there are so many good things."*
> – A Lomond teacher-leader

Many "good things" extended beyond the teachers' learning environments and their interactions with students. Teachers began to discuss their lessons and student work with each other. Collegial relationships and professional discussions encouraged many teachers to take risks and learn mathematics (Pourdavood & Fleener, 1998). It seemed that from these collaborations and common interest among some members of the school community emerged trust, professional respect, and pride in students' abilities to do significant mathematics.

Chapter Five

Complexity of School Change

Radical educational reform abounds with complexity. (Fullan, 1997; Hargreaves, 1997).

School leaders may expect complications when challenging and altering existing educational structures by initiating the reforms of the National Council of Teachers of Mathematics. Creating an epistemological change in learning and teaching may expose weaknesses and flaws in current educational practices. Fundamental changes inherently perturb the existing educational system and, in turn, create external and internal conflicts when a "business-as-usual" mentality reacts to structural reforms. Tensions and conflicts may provide school leaders opportunities to better understand the nature of change and to develop strategies to lead major reform. This reflexive relationship between the status quo and reform may be a source for renewing and sustaining a change process.

An increasing amount of educational research is dedicated to school change and the challenges of leading major reform within an organization that is historically resistant to fundamental change. Within the broader research community it is documented that the process of organizational change is unpredictable, nonlinear, chaotic, and controversial (Capra, 1995; Dooley, 1997; Gleick, 1987; Pourdavood, 1997; Prigogine, 1997; Stacey, 1992; Waldrop, 1992). Furthermore, conflict often accompanies major change and may indicate the depth of changes occurring within the individual and organization.

Fullan (1993) supports the need for new perspectives on educational change. He believes that major educational reform requires a paradigmatic shift. According to Fullan, education has a long, dismal history of unsuccessful reforms: At best, most school reform has been superficial and temporary. He asserts that successful implementation of change does not lie in creating better reform strategies within the current status quo. Fullan's remarks are consistent with the ideas of Senge (1990) and Burrell and Morgan (1988) who argue that understanding the complexity of major organizational change additionally requires the development of new mindsets to understand the complexity and nonlinearity of the change process. This might suggest that in order to understand the nature of major educational reform, educational leaders need to distinguish between differing epistemological perspectives.

Fullan (1993) posits that the goal of educational leaders is to re-conceptualize educational change as an overlapping series of dynamically complex phenomena. Viewing change from this perspective requires a broad range of abilities, such as

> *. . . [an] ability to work with polar opposites; simultaneously pushing for change while allowing self-learning to unfold; being prepared for a journey of uncertainty; seeing problems as sources of creative resolution; having a vision, but not being blinded by it; valuing the individual and the group; incorporating centralizing and decentralizing forces; being internally cohesive, but externally oriented; and valuing personal change agentry as the route to system change.* (Fullan, 1993, p. 40)

The instructional reform at Lomond Elementary School supports the research findings on organizational change in several ways. First, the changes at Lomond ventured far from equilibrium and challenged the status quo within the school. As a result, conflicts emerged that challenged the value of the reform. State-mandated proficiency testing arrived in the middle of the reform efforts. The Proficiency Mathematics test was not directly aligned with Lomond's curricular reforms. Lomond fourth-graders scored about the same as fourth-graders at the other four elementary schools. Most district educators and the public expected the scores to be higher. Because the scores were not higher, the reform seemed to lose some credibility.

Furthermore, during the reform period, a community anti-tax group was formed to defeat school levies and criticize school management, operations, and the instructional program. In their effort to degrade Shaker Heights schools and persuade people not to vote for additional school taxes, they challenged the differences in achievement between African-American and white students (Martin, in press). The achievement gap was most conspicuous in mathematics and science. So, some anti-tax leaders attacked constructivism as a theory for teaching mathematics. These same leaders urged the district leadership to return to direct instruction for basic calculation skills. They promoted the Kumon Mathematics Program, a Japanese skill-based program. The leaders claimed that students should not do problem solving until they first knew their basic facts.

Moreover, as the instructional reform evolved and deepened, the change processes at the school became intensified and caused dissension among some Lomond teachers. Union leadership, at the request of some senior Lomond teachers, reacted to the structural changes, specifically, the creation of a teacher leadership team. The union implied that veteran teachers had been ignored and their talents disregarded (Shaker Heights Teachers' Association Newsletter, November 1996). Union officials also complained to district administrators that some veteran teachers were intentionally excluded from participation on the leadership team (conversation between principal and district administrator, December 17, 1998). An accounting of all salaries and stipends paid during the project was requested.

Second, the major change at the school — mathematics reform — is a change in epistemology. This epistemological change — the movement away from behaviorism toward constructivism — is a paradigmatic shift for teachers. This paradigmatic shift permeated the school environment and changed classroom settings, communication with parents, teachers' interactions, leadership decisions, instructional and assessment practices, and the role of student voices in mathematics classrooms.

Third, the process of change at Lomond was chaotic. This chaotic process challenged existing leadership strategies and interrupted the stability of the school climate, the future was uncertain. Chaos and uncertainty impacted and forged new leadership strategies. The principals developed strategies to prepare and guide teachers for an unknowable journey. Future educational leaders who want to lead school change probably would need to accept a climate of uncertainty and chaos.

Fourth, Lomond's reform seemed to depend on teachers and principals who believed in the need to restructure and reculture schools, and who were willing to take risks and spend the time necessary to do this. It could also be concluded that students played a role as change agents. Student voices and experiences acted as catalysts for teacher development, deepening teachers and students' mathematical understandings.

The findings of the case study are also consistent with Kuhn's (1970) assertions about understanding the complexity of radical change. He, too, believed that major change is not linear, sequential, or accumulative in nature. Instead, he argues that changes explode on the scene when "[P]resent laws and rules are not fitting with new information or when new theories or information fit better, causing professional insecurity" (Kuhn, 1970, p. 67).

Kuhn's idea of revolutionary change as explosive is echoed in Papert's book, *The Children's Machine* (1993). Papert documents the power of two trends that are converging and driving the current revolutionary change in education. These converging trends are (1) technological as evinced by the creation of the computer, and (2) epistemological as evinced by recent reforms in language arts, mathematics, and science, which necessitates, according to Papert, an alternative view of knowledge reflective of constructivism. Papert argues that educational leaders must develop new models to effect major change. He is critical of current approaches in educational reform that depend on improved test scores as indicators of effective school change. He believes that educational reform, with its fetish for objective, standardized testing to show the attainment of goals, fails to provide any plan for viewing the learning environment in a more meaningful way, and fails to allow for the emergence of responsive learning communities.

Additionally, Papert asserts that educational reforms misinterpret the kind of changes needed in education. He believes current reforms still view learning as an accumulation of facts and skills. He suggests that "megachange" in education may occur only through a grassroots approach, the emergence of "little schools," where teachers, parents, and children explore and create new learning situations, and where networking among these schools would prevent isolation and provide an opportunity to incorporate successful changes from a diverse environment.

Lomond's mathematics instruction reform was radical because it did not fit within the existing organizational structure. The school de-emphasized the reliance on textbooks and objective standardized tests as the only measure to evaluate student progress. Instead, Lomond educators used new materials and designed an instruction-assessment framework to capture student growth. This framework required more time than textbook lessons and report cards. Additionally, the Lomond principals publicly challenged the universality of knowing basic skills as an indicator of mathematical knowledge and whether basic skills were sufficient to prepare students for a technological society.

Furthermore, instructional change at Lomond exploded on the scene when the recommendations from the NCTM *Standards* (1989; 1991; 1995) were found not to be congruent with existing practices and epistemology. Overall, it can be stated that the Lomond reform process may reflect Papert's idea of megachange. The reform was a grassroots approach, teacher by teacher, room by room. Out of this process gradually emerged a little school. "Do you realize how different you are from other schools? You guys look at school so differently," said a Shaker parent.

Within all these internal and external complexities there may be good news for fundamental change in instruction, organization, and professional development. It is not unusual for good news to emerge from within a climate of constant conflict and disequilibrium (Fullan, 1997; Stacey, 1992; Wheatley, 1994). However, good news may depend still on the following uncertainties: (1) Can this or any instructional reform exist beyond the building level? (2) Will other educators take risks to promote school change? (3) What is the fate of this school community and those individuals who have taken major risks to change traditional beliefs and practices? (4) Does this constructivist model of mathematics instruction improve children's learning? (5) How will improvement in student's understandings be meaningfully evaluated? and (6) How can schools be restructured to facilitate and encourage fundamental change? These questions are echoed by many voices in the Lomond school community.

There is hope that school communities like Lomond will take risks to restructure and recreate themselves as places where children's sense of wonder, curiosity, imagination, and creativity are valued and used in the construction of knowledge — places where children become educated persons.

> *I want my child to be challenged to learn. I would like her to have a variety of interests and pursue things even if she is not the best at it.* – A Lomond parent-leader

EPILOGUE
REFLECTIONS

It may be risky business, but let's not forget that it's for kids. – Lomond principal

"He's still interviewing," said Judy, the secretary, as Roland and Ray came into the outer office and sat in the chairs on opposite sides of the doorway. They were familiar faces to Judy. Both men — one a secondary mathematics teacher, the other, a university mathematics professor — spent time at the school, working with teachers and consulting with the principals about mathematics and the reform initiative.

"That's OK," responded Roland. "We'll find Lynn and start organizing the presentations for AERA [American Educational Research Association]." He stood up and reached down to pick up his briefcase.

"But Lynn's interviewing, too," Judy quickly added.

"Oh, so the applicant is being double-teamed, huh? We might be here all night," kidded Ray who sprawled back in his chair to make himself more comfortable while he waited.

"Now, Ray," she scolded. "They don't 'double-team' the applicants. Lynn and Larry take turns with their questions. They cue each other. They're trying to be more efficient, since they've had so many applicants for the kindergarten position."

Judy grabbed a brown grocery bag on the floor and placed it on top of her desk amid the scattered papers.

"Here, you guys," she said, "remember to take this bag with you. I bought you soda, pretzels, and sandwiches for later this evening."

"There must be some mistake," said Ray. "We're going out to dinner afterwards."

The secretary, somewhat puzzled, looked over at Roland.

"I didn't tell him yet, Judy," explained the professor.

"Tell me what?" asked Ray. "I thought we were celebrating the end of the case study?"

"Lynn said your celebration will have to wait," explained the secretary. "The University of Toronto doesn't think you folks are quite done writing yet. Dennis faxed a second set of revisions today. This time, instead of 12 single-spaced pages, you guys have only six. So no dinner tonight, just this stuff to munch on."

"Maybe you should have gotten us bread and water, instead," offered Ray.

The three laughed. Just then the door to the principal's office opened and a pale young woman emerged.

"Remember," Larry said to the woman. "As soon as I know something definite, I will give you a call. If you have an offer from another district, please let me know before you sign another contract."

"I'll do that. Thank you. It was a pleasure talking with you."

She shook the principal's hand, turned and walked toward the doorway.

"Wait!" yelled Lynn from inside the principal's office.

The woman turned around in the doorway.

"You forgot your portfolio," said Lynn as she handed the applicant the shiny brown leather case.

The woman smiled, took the case and disappeared into the hallway. Roland and Ray gathered up their briefcases and walked into the principal's sunlit office. The room was warm. The principal turned the window air conditioner on low.

"How'd the interview go?" asked Roland, settling himself in a chair next to Larry's wooden credenza which was littered with phone messages and plants.

Ray removed a stack of students' mathematics papers from another chair and sat down facing Larry's desk. His desk resembled Judy's: cluttered with file folders, boxes of papers, and research articles. The old air conditioner hummed loudly.

"Not bad. She has potential, I think."

Lynn pulled in an extra chair from the outer office through the doorway.

"Yeah, he'll probably hire her," said Lynn, as she struggled to keep the door open and move the chair inside. "She talked about Piaget and Vygotsky pretty intelligently. I was impressed. She even had an interesting answer to my '24 hours in a day' story."

"Hey, Larry, how long did you talk with her about constructivism?" teased Ray.

"Too long," replied Larry, shaking his head. "It's getting harder and harder to find people who have a sense of this stuff. The stakes keep getting higher. I can't believe how complex this whole thing is."

"I suppose planning for the presentations at AERA and writing the case study didn't help," offered Roland.

"You've got that right," Larry shot back.

Lynn leaned forward in her chair.

"Yeah, well, don't get Larry started on how much time this case study has taken," warned Lynn. "Let's just get down to business and figure out these presentations so the audience gets some idea of what's been happening in this reform. It's been suggested we reflect on pivotal events in the reform — how those events molded the change process. What do you think?"

"Sounds good to me," answered Roland, "except that change is dynamic. It continues to evolve. So, perhaps it is best to talk about a few key events."

Ray took a white legal pad from his briefcase on his lap. "I jotted down a few ideas that, at least for me, I thought were important. We can decide if they qualify as 'pivotal.'"

"Go on," encouraged Larry. "Let's see what you've got there."

"Well, certainly for me, that one hot afternoon in May when we identified the key math concepts was important. Without the key concepts —"

"— And Larry threatening not to pay anyone until we 'discovered' them —" interrupted Lynn.

Ray chuckled, "Yes — and under penalty of non-payment, those concepts emerged from our notes on the blackboard. I remember sitting in the back of the room with Dr. Anderson. We were so surprised! The key ideas made so much sense. It made mathematics so clear."

A slight smile crossed Ray's face as he continued, "I also remember that your teachers thought Tim and I had 'set them up.' They assumed that we, as mathematicians, knew the key ideas in mathematics all along and were waiting for them to discover them. I had a terrible time convincing some of them that I really had no clue about major ideas in mathematics — only major topics. There is a big difference. Even Tim and I, with all our years teaching math, never really thought how pervasive unitized systems were in mathematics. And that all mathematical operations somehow involve combining, comparing, and partitioning. That's important stuff."

Ray looked again at his notes. "Anyway, I wrote 'key ideas' down, because without the ideas and the processes, the reform would have been different."

"What do you mean?" asked Larry.

"Well, just think," mused Ray. "Where in education do you condense the curriculum to 'ideas' and then take important ideas and revisit or spiral them year after year? In math, we organize and cover major topics such as probability, geometry, and metric measurement. But we never talk about the ideas fundamental to those topics. It's all so interesting to me . . . and to think it was a group of elementary teachers who did this. That's amazing in itself. You guys have little training in mathematics. How dare you folks restructure my discipline!"

"I agree with Ray," added Roland. "Restructuring the mathematics curriculum around key events and key processes are a pivotal events, because it somehow took teachers out of the role of 'deliverers of curriculum' into 'designers of curriculum,' where teachers became more intellectually focused."

"Would you be willing to talk about this at AERA?" inquired Lynn. "Do we agree that restructuring mathematics was pivotal? Remember, too, we each only have five to 10 minutes."

Larry sighed, got up, and moved his chair from behind the desk and turned down the air conditioner. He sat next to Ray.

"Ray, you're right about the key ideas, but we can't make it too much 'pie in the sky,'" he grumbled. "It's not an easy thing to get teachers and administrators to think beyond a long list of behavioral objectives. Most curricular guides list 50 to 60 objectives for each grade level. When you focus on key ideas and processes, most people think you're missing the objectives. So, whatever you do to organize your part of the presentation, do not give the audience the impression that this restructuring was accepted and applauded. The fact was, it was not."

"That's an important point, Larry," said Roland. "Someone should talk about the cultural barriers in this reform and how you tried to avoid them."

"— Or dismantle them completely," laughed Lynn. "They were a constant challenge. But there were benefits: the barriers showed our teachers how rigid education is, and that encouraged some of them to change."

"Yes, I agree with that, but I think our audience would like to know how you tried to manage uncertainty, complexity, and chaos while confronting these barriers" added Roland.

"Cultural barriers were significant — real significant," Larry stated. He gazed out the window. "The trouble is we have a business, supposedly an important one, where the professionals, with the support of the public, work part time — 186 days each year, less than six hours of instruction a day. No instruction for 12 to 14 weeks. Now, within this schedule, teachers are expected to make sure children learn. Further, this is a business where about 30 to 40 percent of our students are not meeting state standards. Now, I ask you. What company would be successful if it was only opened for part of the year? And on top of that had to recall one-third of their products each year?"

Ray jotted some notes on his paper. "So cultural barriers, particularly the 'part-time' profession, sounds like an important thing to mention. But does 'cultural barriers' qualify as a pivotal event?"

Larry turned and looked at Ray. "The barriers are pivotal conditions. They are the mindsets and structures that can stifle and suffocate change."

"Yeah," reminded Lynn: "Remember when we told the teachers that they had to teach 90 minutes of mathematics each day instead of 45 minutes? Some teachers thought we were nuts!"

"Ninety minutes of mathematics each day? I'd love to have 90-minute classes," responded Ray. "These 50-minute classes at the high school do not give kids enough time to learn. Out of those 50 minutes there's maybe 35 minutes of instruction."

"It seems," added Roland, "that NCTM is the culprit in all of this."

"What do you mean, Roland?" asked Lynn.

"Well, at first the reform appeared to just challenge mathematics curriculum and instruction, but it really challenged the whole time structure. It seems to me, you can't recommend expanding the curriculum and develop deep understandings in mathematics without expanded time."

"And you can't teach according to constructivist theory without more time to teach," Larry added. "Teachers need time to listen to what students know and don't know. Students need time to build models, write, draw pictures, and make graphs. This kind of instruction can't happen within the confines of 45 minutes. The irony in all of this is that the old model of teaching mathematics — the feed-in, feedback model, objective tests, skill and drill — was efficient. In most cases, teachers could get it done within the school year."

"Yeah, Larry, but that old model drove people out of mathematics," Lynn reminded him. "Most of our teachers, including me, got out of mathematics as soon as we could. We never thought those equations made any sense. Why were we learning all this stuff? What relevance did it have? My father spent hours trying to convince me that there was a purpose for mathematics other than balancing a checkbook and figuring out tips. He just wasn't convincing enough. I never understood, until this reform, where and how mathematics is in everything I do." Lynn laughed. "I guess that's another irony: that I would learn more from children about mathematics than I ever learned in my schooling."

"What about the changes in assessment?" added Ray, trying to keep the focus of the meeting. "That definitely was a pivotal event. Or was it a 'pivotal condition'?"

The others laughed.

"You can laugh all you want, but the assessment component is really important," Larry retorted. "If we cannot design good authentic assessment instruments and create the time to use them effectively, then no matter how good the teaching, instruction is inhibited. The problem is, though, people believe in report cards. They don't realize how primitive they are. Report cards lack evidence of what students really can do and what they know. You can't understand all that unless you talk with students and see what they do."

"You know, I didn't believe that about report cards, Larry," responded Lynn, "until that day I taught money in kindergarten. Remember?"

Larry nodded.

Lynn continued, "The problem was how to split up $10 between two friends. Before I started the lesson, I wanted to know what the kids knew about $10. So, I kinda digressed —"

"Just like you're doing now," teased Roland.

Lynn paid little attention to his teasing and kept talking, "— and decided to ask the children, 'how many ways can you make $10, using just paper money?' Well, the first two students gave me what I expected: 10 one-dollar bills and two five-dollar bills. At that point, I almost went on with the lesson. But I didn't, and asked, 'any other ways to make $10?' A child handed me five one-dollar bills and one five-dollar bill. I was surprised. I didn't expect to see this. The funny thing was, most of the students seemed to know this already. So, to tease the class a little, I asked the question again. I knew there weren't any other answers. A little girl went over to the pile of play money and looked carefully through the stack of bills. She pulled out five two-dollar bills. I was shocked! That got me thinking about report cards and learning objectives. They may not reflect what children do know and experience. On the kindergarten report card, there is nothing about dollars — only recognizing the difference between a penny and a dime. Size and color — how difficult is that?"

"Assessment beyond report cards was significant," stated Roland, redirecting the conversation back to their presentation. "I came here just after teachers began implementing *Snapshots*. I was interested in how you planned to capture student growth in mathematics. I think this initiative was pivotal."

"But the assessment system still isn't finished," responded Lynn. "Can growth be captured and evaluated through pictures and words? We are trying to develop a rubric, but how do you assess individual growth? We are still struggling with this part."

"I'm not so sure, Lynn, that we need to dwell on what isn't finished," added Larry. "What should be mentioned is the fragile nature of authentic assessment. Again, no time to do this. Teacher-student-parent conferences need more time. Union and management leaders need to understand this. More time for assessment, I guess, isn't a budget priority. Extra time means extra money."

Lynn stood up, walked over and turned the air conditioner on high.

"You know, it's scary," she reflected. "What we wrote in the grant proposal six years ago has come back to haunt us. Remember, Larry, we had to list in our proposal what we thought might be 'hindrances to school improvement'?"

Larry laughed, "All too well. It caused some controversy. People took it very personally."

"Anyway," continued Lynn, "we listed several hindrances. We said that both union and management leaders might lack the desire to make fundamental school change. They might 'play it safe' and stay with 'business as usual.' They may accept that all children can learn. Now I know why people don't get involved in major change. It takes incredible time and energy. Also, the politics of change can be paralyzing. Maybe only fools venture into this territory."

"Then why go forward? Why continue to swim upstream?" asked Roland. "That's what I find interesting about the people here. Most of your teachers continue to go forward, make change, regardless of the resistance, regardless of test scores.... Why?"

"Well," replied Larry, "maybe we're all a little foolish. But all of this is for kids. The way I look at this is, we've all planted seeds. The seedlings are growing, because they are nurtured by teachers, parents, and our students, who believe this is how mathematics should be."

"Yeah," responded Ray. "We should all feel very good about this. There's been lots of good things happen here. Kids love mathematics. That's a real positive! Your teachers have come so far in all of this. You've got to be pleased."

"But," grumbled Larry, "who will continue to make these good things happen? Who will continue to tend the garden? Who will train the gardeners?"

Lynn leaned back in her chair and stared at the ceiling. A slight smile crossed her face.

"Maybe the 'crazies down the hall' will."

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APPENDIX A

Theoretical Assumptions

The theoretical and philosophical assumptions of this study are grounded in autopoiesis systems theory (Maturana, 1980, 1981, 1988) and emergent perspective (Cobb & Yackel, 1996). Maturana defines autopoiesis as a self-producing, self-organizing, and self-sustaining entity. Autopoiesis theory argues that a living system must be understood through the process of the system's interaction with its environment. An interactively open system cannot be studied in isolation: it must be studied through the process of "structural coupling" (Maturana, 1988). Structural coupling means the reflexive relationships between the system and its local situation, the cultural/historical condition (Hatch & Gardner, 1993) and other systems, to include individuals and events. The social context does not and cannot determine the change but triggers or perturbs the changing process emerging through the individuals. The changing nature of this emergence is inherently an autonomous process and comes from within the individual (Fleener & Pourdavood, 1997; Hargreaves, 1997). Autopoiesis is consistent with emergent perspective. According to emergent perspective, knowing and learning is constantly evolving and is constructed by the individual within the social and cultural condition. "Learning is a constructive process that occurs while participating in and contributing to the practices of the local community (Cobb & Yackel, 1996, p. 185). Autopoiesis theory and emergent perspective play a guiding role for the researchers to understand the dynamic nature of the complex interplay of instructional reform on school change and the emergence of instructional leadership.

Research Design and Methodology

This qualitative research methodology is grounded in the constructivist inquiry of Lincoln and Guba (1985; 1994). This methodology is consistent with the theoretical framework of this research study and its opposition to a positivistic approach to inquiry.

Lincoln and Guba (1985; 1994) point out three major philosophical differences between positivistic and constructivist inquiry. These three distinctions are ontological, epistemological, and methodological differences. Ontology refers to the nature of reality. Epistemology relates to ways of knowing. Methodology defines how we do research.

In a general sense, the positivist views reality as something tangible out there. Therefore, reality can be predicted and controlled. The constructivist views reality as local and context-specific. As such, reality, according to constructivists, is shaped by experience and social interactions. Hence, reality cannot be predicted and/or controlled. Ontological differences between positivist and constructivist perspectives have implications for epistemological differences. The positivist sees the relationship of knower and known as dualistic and objectivistic and suggests that the knower can operate independently from the known. The constructivist sees the relationship of knower and known as dialectical and suggests that the knower and known are interactively related and, thus, influence one another.

Ontological and epistemological differences between the positivists and constructivists are closely connected to the ways they do research. The positivist sees a linear relationship between cause and effect, and argues that research is value-free and that the goal of research is to generalize findings. The constructivist believes that researcher and the researched interact and are interconnected. It is impossible, therefore, to distinguish cause from effect. The constructivist questions the generalizability of any research finding in positivist terms, arguing that research is value-dependent.

Lincoln and Guba (1985; 1994) suggest the approaches for establishing trustworthiness of interpretation and analysis of research findings. They focus on four criteria namely credibility, transferability, dependability, and confirmability. Credibility refers to certain activities that increase the probability that the findings will be authentic. One such activity is investment of time. It is imperative that the inquirer spend time becoming oriented to the situation. There is no answer as to how much time is needed to become familiar with, and accepted by, the group being studied. One indication of credibility is acceptance of the findings by all the participants, including the researchers. Data, analytic categories, interpretations, and final findings must be examined by the members who provided the information. Lincoln and Guba (1985) call this "member checking." Member checking continually occurs through the data collection process and is an important component of credibility.

The second component of trustworthiness is transferability. Transferability refers to the potential for others to identify with the research context and apply the findings to their own particular situation. Transferability is obtained through the provision of "thick description" (Denzin, 1988; Lincoln & Guba, 1985; 1994).

The third component of trustworthiness is dependability. Lincoln and Guba (1985) describe dependability as a means of establishing reliability. Dependability can be established in two ways: through the use of inquiry teams or the use of the audit. An auditor examines the process by which the data were collected and is closely connected to confirmability, the fourth component of trustworthiness.

The major approach for establishing confirmability is the audit and/or member checking. There are several substeps in this approach. The first is to determine if the findings are grounded in the data. Observations, interview notes, and document entries are examined. The auditor or members of the research team look for clarity and explanatory power in the description that accompanies the data. Inquirers' "subjective I" (Glesne & Peshkin, 1992) is reviewed to determine the extent to which the inquirers resisted early closure.

Therefore, the researchers used a methodology which would best serve them in their attempts to investigate the dynamics of school change within the assumption "that the issue at hand turns in some way on the ways in which individuals conceive of or construe their world" (McCracken, 1988, p. 59.). This construction is multiple, dynamic, and mental (Lincoln and Guba, 1985; 1994).

The research methodology is characterized by the following features (Bogdan & Biklen, 1982):

1. a natural setting as the direct source of data
2. the researcher as "developer"
3. the research as descriptive
4. researchers' concern for process over outcomes and product
5. inductive analysis
6. analysis supported by phenomenological and ideational theory which accept multiple realities and suggest change is the result of an individual's thoughts and ideas
7. meaning as the essential concern

Data Sources

Data sources of this study include: (1) transcripts of audiotapes of long interviews of key informants, (2) transcripts of audiotapes of mathematics classroom activities and interactions, (3) fieldnotes of the university researcher, (4) related documents (e.g., participant's dissertation, grants, teacher-designed instruction and assessment activities, teacher-parent newsletters, school newspaper, student mathematics portfolios, memos, weekly schedules), and (5) follow-up interviews with key informants.

Data Collection and Data Analysis

Data collection consisted of two phases: (1) preliminary phase and (2) the active phase. The preliminary phase of this study began June 16, 1997, and ended September 6, 1997. The purpose of this phase was to establish a research framework and to discuss and decide the following issues: (1) defining the research questions; (2) establishing a timeline for research activities; (3) targeting potential interview candidates; (4) clarifying the roles of the case-study team members that consisted of the university researcher (Roland), the Lomond principal (Larry), the assistant principal (Lynn), a secondary mathematics teacher (Ray), and a graduate assistant (Sharon); and (5) defining the research study as "research as development," where the case-study team members, who were active participants in the reform, were also the authors of the case study.

The active phase of the data-collection process began September 11, 1997, and continued through March 15, 1998. It included classroom observations, long interviews, group discussions with teacher leaders, related documents, and fieldnotes of parent-teacher-student conferences. All classroom observations, and one-on-one interviews were audiotaped and transcribed. Transcriptions were edited by the interviewers for clarification and modification. Key informants' transcripts were read by the case-study team. Transcripts of other participants were read by the university researcher in order to comply with issues concerning confidentiality.

Data collection and data analysis occurred simultaneously during the course of the study. Constant comparative data analysis (Lincoln & Guba, 1985, 1994; McCracken, 1988) was used for data analysis. Based on the emerging patterns and themes, several categories were developed to describe the complexity of mathematics reform and school change.

The categories that emerged from individual readings and extensive group discussion were: (1) multiplicity of the nature of change such as structural change, leadership change, and individual change, and (2) internal and external complexity of school change. Structural change is defined as changes in the use of time, physical environments, materials/equipment, learning/teaching practices, and changes in roles and relationships. Structural change is related to leadership change. Leadership change relates specifically to how roles and relationships within Lomond School are understood and applied. Individual change is closely connected to structural change and leadership change. Individual change represents changes in individuals' beliefs, values, and practices.

APPENDIX B

SAMPLES OF PERFORMANCE TASKS GRADES K to 4

Note: The following are performance tasks designed by Lomond teachers to capture and monitor students' cognitive growth in mathematics and problem solving. These tasks — chance, time and money, length, area, and volume — are instructional targets for teachers. Teachers are expected to select lessons that will help student performance on these tasks. These topics are spiraled throughout kindergarten through fourth grade and are revisited during the school year. Solutions for the tasks involve one of three processes: combining, partitioning, and comparing (basic operations). Performance tasks are given to most students three times during the year. Copies of students' final attempt in May each year are collected and saved in students' authentic folder over a five-year period. All teachers read and discuss these tasks with students first. Together with their teacher, students find important information and suggest strategies and materials to use in finding solutions. Often, during these mathematics dialogues, students solve the problem. Nevertheless, all students are required to solve the problem independently — defending their solution with illustrations, words, and calculations.

Chance

Kindergarten

Ms. Grieshop's kindergarten class decorated special shirts. Each child had to glue a red, blue, and yellow button straight down the front of each shirt. Ms. Grieshop did not want all the shirts to look exactly the same. How many different ways can the three buttons be arranged so that all the shirts are different?

First Grade

Brandon is going on vacation for one week. Each day he wants to wear a different outfit. He packed three T-shirts: a red, a blue, and a yellow one. He packed black shorts and brown shorts. He also had two kinds of shoes — sandals and gym shoes. How many different outfits could he wear? What would they look like?

Second Grade

In the Duck Pond game, 12 large plastic ducks float around in the baby wading pool. Although all the ducks look the same from the top, their stomachs are painted either red, blue, or green. If a player picks a duck with a red stomach, then the player wins a book from the bookstore. How could the colors of the ducks' stomachs be painted so that the player would

- be certain to win a book?
- be likely to win a book?
- equal chance to win a book?
- not be likely to win a book?
- be impossible to win a book?

Third Grade

You were asked to design three spinners for the Spin to Win game at the Lomond Pumpkin Affair. Each spinner must have at least three different colored sections. Red must be one of the colors in all three spinners.

- Spinner One: Design the spinner where red is most likely to win.
- Spinner Two: Design the spinner where red is not likely to win.
- Spinner Three: Design the spinner where red is not likely to win.

Test the three spinners. Collect and record the data. Explain the results.

Fourth Grade

For a mathematics project, Paula designed a game of chance. She challenged her class to figure out two things. First, does everyone have the same chance to win? Second, is there a strategy for winning or is the winner just "lucky" — that anyone can win? Here were the rules to Paula's game:

Materials: two dice, paper for recording numbers

1. Players select a number from 2 to 12.
2. Players take turns rolling the two dice. The **sum of the two** dice is recorded by one player. For example, if a player rolls a 4 and a 6, the number recorded by the player is 10.
3. Players continue to take turns until the dice has been rolled 50 times.
4. Players whose **sums** (number) were rolled most wins the game.

Length (distance)

Kindergarten

The beanstalk that Jack planted grew really fast! After five days, the beanstalk grew 15 unifix cubes tall. How much did the beanstalk grow each day if it grew the same amount each day?

First Grade

Jack's beanstalk is 16 units long. The giant's beanstalk is 32 units long. Jack's mother's beanstalk is 24 units long. Compare the height of all three beanstalks. What did you find out? Explain your solution using pictures, words, and numbers.

Second Grade

Randy bought a 72-inch-long submarine sandwich for his sleepover party. He invited three friends to the party. Submarine sandwiches cost $2.50 for every 12 inches of length. If Randy divided the sandwich evenly between himself and his three friends, how long a sub sandwich will each person get to eat?

Third Grade

Every day, Sean took Rex, his grandmother's dog, for a long walk around the nearby high school. The total distance Sean and Rex walked each day was 3.5 (3 1/2) kilometers. Erica, Sean's cousin who lived next door, took her dog, Spot, for 5.25 (5 1/4)-kilometer walks four times a week. In one week, who walked the dogs farthest?

Fourth Grade

Rapunzel, a heroine in a Grimm's fairy tale, never cut her golden hair. It was so long that when she was imprisoned in a castle's tower, she let her hair hang down outside the turret window so people on the ground could climb up to see her! Human hair grows about 1/2" each month. If the distance from the turret window to the ground was 20 feet, how old was Rapunzel in the fairy tale?

Time and Money (rate)

Kindergarten

Robert saved $2.00 every day for six days. How much money did Robert save in six days?

First Grade

Shenise will "dog-sit" for her neighbor's dog for four hours. She dog-sits from 4:30 in the afternoon until 8:30 in the evening. Each hour Shenise dog-sat she earned 2 pennies, 1 dime, and 1 nickel. How much money did Shenise earn dog-sitting?

Second Grade

Tonya wanted to buy a bunny, a cage, and a month's supply of bunny food. The total amount of these three things was $36.00. Tonya earns $4.50 each week doing chores around the house. Design three ways that Tonya could save her money to buy the bunny and the other items. Explain which of the three plans you would tell her to use and why.

Third Grade

Ellen earns money babysitting. She wants to save her money to buy a portable CD player that costs $128.00. Ellen charges $4.50 per hour to babysit during the day and $5.50 per hour after 8:00 p.m. Mr. Holmes hires Ellen to watch his two grandchildren every Saturday in May from 3:30 p.m. until 11:00 p.m. How much money does Ellen earn in one Saturday?

Fourth Grade

Every summer, Jessica's father drives to Chicago, Illinois, to visit family and friends. Jessica and her father live in Shaker Heights, Ohio. The distance between Chicago and Shaker Heights is about 360 miles. Usually, her father drives about 65 miles an hour. The car can travel about 20 miles on one gallon of gasoline. Gasoline costs about $1.30 per gallon. How long will it take them to get to Chicago?

Area (covering)

Kindergarten

Baby Bear was going on a picnic and she wanted to take a lot of brownies with her. Baby Bear's mother had three different size trays.* One tray was a square, and two trays were different-sized rectangles. How many brownies does each tray hold? Which tray holds the most? Which holds the fewest brownies?

* Students are given paper trays and colored tile "brownies" to solve the problem.

First Grade

Little Red Riding Hood built a new cabin in the woods for her grandmother. The cabin had four rooms — a living room, a kitchen, a bedroom, and a bathroom. The total area of the cabin was 24 square units. Design a floor plan that has 24 square units. Show where all the rooms are. How many square units are in each room?

Second Grade

Mr. Kmitt's students bought a gerbil, Squeaky, for their classroom. Each weekend, a student took Squeaky home in a little gift box. The boys and girls decided to make a "paper carpet" for the bottom of the gift box. They measured the bottom of the box. Each side measured 7 units. What was the area of the bottom of the box?

Third Grade

Jasmine bought carpet for her bedroom. Her room measured 10 feet x 15 feet. What was the area of the bedroom? How much floor space is left after Jasmine puts her furniture in her room? Design a scale model of the floor plan of Jasmine's bedroom. Include her furniture in your scale model.

Jasmine's bedroom furniture:

1 desk	4 ft. x 2 ft.
1 bookcase	3 ft. x 1 ft.
1 nightstand	1 ft. x 2 ft.
1 dresser	3 ft. x 2 ft.
2 beds	7 ft. x 4 ft. (each bed)

Fourth Grade

Mrs. MacGregor decided to build a large pen for her dog, Rex. Mrs. MacGregor bought the supplies at the hardware store. She purchased 36 meters of wire fencing. The fencing cost $9.00 per meter. She paid a 7% sales tax on the fencing. Draw and label some of the possible dimensions for Rex's pen. What pen will provide the maximum area for the dog?

Volume (filling)

Kindergarten

Marcus had three different sizes of plastic glasses.* He wanted to find out which glass would hold the most amount of milk. How could Marcus find out which glass holds the most? Which glass holds the least? What glass holds a "middle" amount? Draw a picture of your solution.

*The shapes of the glasses are deceiving so that the students can't tell by the height of the glass.

First Grade

You are going to take fudge to a Cleveland Indians baseball game. Your mother has given you three boxes* for carrying the candy. You want to take the most amount of candy with you. How would you decide which box holds the most fudge? Compare the volume of all the boxes.

* Students are given a variety of jewelry gift boxes.

Second Grade

Cinderella's fairy godmother gave her a magic cube on her first birthday. Each edge of the cube was one unit long. When Cinderella woke up on her second birthday, the magic cube had grown. It now measured two units on each edge. On every birthday, the cube magically grew one unit longer on each edge. Record the dimensions and volume of Cinderella's magic cube for each of Cinderella's first four birthdays.

Third Grade

Charlie, the owner of a chocolate factory, invented chocolate sugar cubes to make milk into hot chocolate. Each cube is one cubic centimeter. He packed the sugar cubes in boxes that measured 4 cm x 5 cm x 3 cm. Charlie sold seven boxes of chocolate sugar cubes. He made $8.75. How many chocolate cubes fit in one box?

Fourth Grade

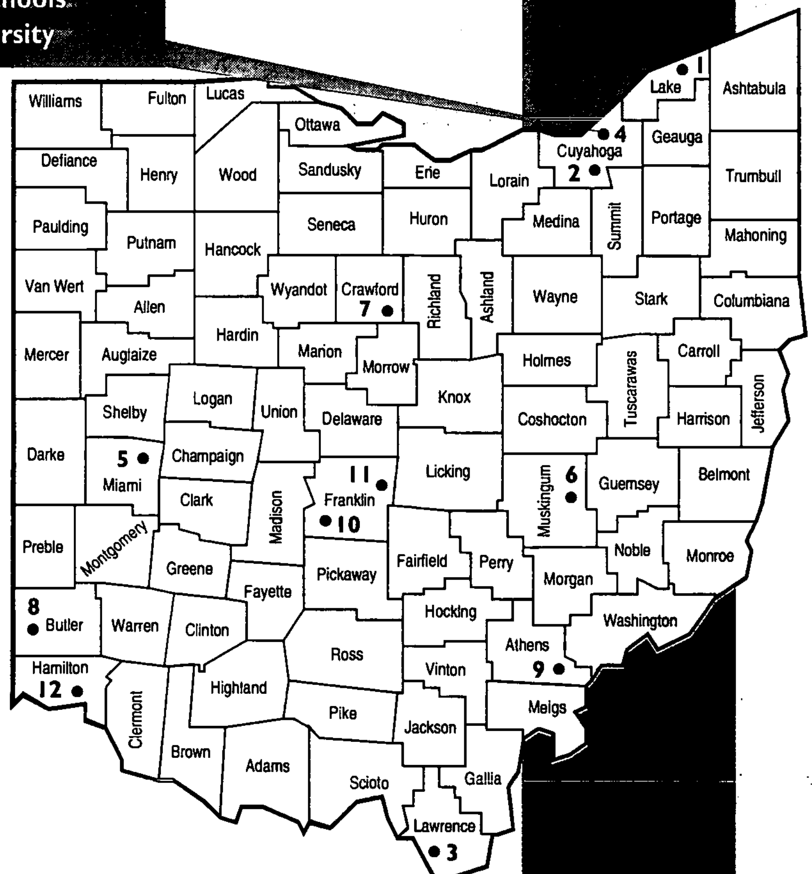
Ryan used the following recipe to make punch for his birthday party.

Ingredients	Cost of Ingredients
3/4 liter cranberry juice	$2.40 per liter
.5 liter apple juice	$1.60 per liter
1 liter ginger ale	$1.00 per liter
250 ml lemonade (optional)	$0.80 per 500 ml

Approximately how many people would this recipe serve, if everyone had 500 ml of punch to drink?

TRANSFORMING LEARNING COMMUNITIES SITES

LOMOND ELEMENTARY SCHOOL
Shaker Heights City Schools
Cleveland State University



ELEMENTARY SCHOOLS

1 **Brentmoor Elementary School**
Mentor Exempted Village Schools
Cleveland State University

2 **Cranwood Learning Academy**
Cleveland City Schools
Cleveland State University

3 **Dawson-Bryant Elementary School**
Dawson-Bryant Local Schools
(Lawrence County)
Ohio University

4 **Lomond Elementary School**
Shaker Heights City Schools
Cleveland State University

5 **Miami East North Elementary School**
Miami East Local Schools
(Miami County)
Miami University

MIDDLE SCHOOLS

6 **East Muskingum Middle School**
East Muskingum Local Schools
(Muskingum County)
Muskingum College
Ohio University

7 **Galion Middle School**
Galion City Schools
The Ohio State University

8 **Talawanda Middle School**
Talawanda City Schools
Miami University

SECONDARY SCHOOLS

9 **Federal Hocking High School**
Federal Hocking Local Schools
(Athens County)
Ohio University

10 **Franklin Heights High School**
South-Western City Schools
The Ohio State University

11 **Reynoldsburg High School**
Reynoldsburg City Schools
The Ohio State University

12 **Robert A. Taft High School**
Cincinnati City Schools
Miami University

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